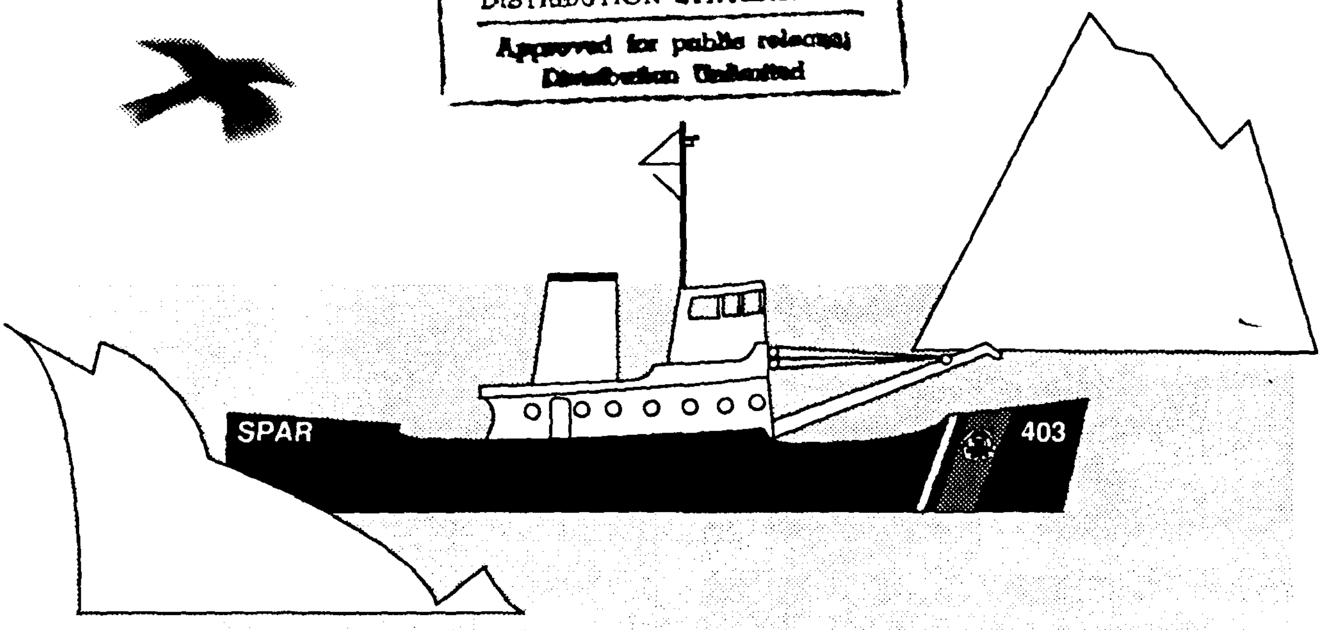
U. S. Department
of Transportation
United States
Coast Guard

Report of the International Ice Patrol in the North Atlantic



USCGC SPAR (WLB-403)
1990 International Ice Patrol Cruise

1990 Season
Bulletin No. 76
CG-188-45

U.S. Department of Transportation
United States Coast Guard

Commandant (G-NIO)
United States Coast Guard

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Bulletin No. 76

REPORT OF THE INTERNATIONAL ICE PATROL IN THE NORTH ATLANTIC

Season of 1990

CG-188-45

Forwarded herewith is bulletin No. 76 of the International Ice Patrol describing the Patrol's services, ice observations and conditions during the 1990 season.

W. J. ECKER
Chief, Office of Navigation Safety
and Waterway Services

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INTERNATIONAL ICE PATROL 1990 ANNUAL REPORT

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Introduction

This is the 76th annual report of the International Ice Patrol (IIP). It contains information on Ice Patrol operations, environmental conditions, and ice conditions for the 1990 IIP season. The U.S. Coast Guard conducts the International Ice Patrol Service in the North Atlantic under the provisions of U.S. Code, Title 46, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea (SOLAS), 1974, regulations 5-8. This service was initiated shortly after the sinking of the RMS TITANIC on April 15, 1912 and has been provided annually since that time.

Commander, International Ice Patrol, working under Commander, Coast Guard Atlantic Area, directs the IIP from offices located in Groton, Connecticut. IIP analyzes ice and environmental data, prepares daily ice bulletins and facsimile charts, and replies to requests for ice information. IIP uses aerial Ice Reconnaissance Detachments and, when necessary, surface patrol cutters to survey the southeastern, southern, and southwestern regions of the Grand Banks of Newfoundland for icebergs. IIP makes twice-daily radio broadcasts to warn mariners of the limits of all known ice.

Vice Admiral H. B. Thorsen was Commander, Atlantic Area and CDR J. J. Murray was Commander, International Ice Patrol, during the entire 1990 ice year.

Summary of Operations, 1990

The 1990 IIP year (October 1, 1989 - September 30, 1990) marked the 76th anniversary of the International Ice Patrol, which was established February 7, 1914. IIP's operating area is delineated by 40°N - 52°N, 39°W - 57°W (Figure 1). During 1990, Coast Guard HC-130H aircraft equipped with the AN/APS-135 Side-Looking Airborne Radar (SLAR) flew 30 ice reconnaissance sorties, logging over 186 flight hours, and Coast Guard HU-25B aircraft equipped with the AN/APS-131 SLAR flew 23 reconnaissance sorties, logging over 70 flight hours.

IIP personnel flew aboard Canadian Ice Patrol ice reconnaissance flights on January 31 and February 26 to determine the preseason iceberg distribution. Based on the latter deployment, the 1990 IIP season was opened on March 9. From this date until August 7, 1990, an aerial Iceberg Reconnaissance Detachment (ICERECDET) operated from Newfoundland one week out of every two. The season officially closed on August 15, 1990.

Watchstanders at IIP's Operations Center in Groton, Connecticut analyzed the iceberg sighting information from the ICERECDETs, along with sighting information from commercial shipping and Atmospheric Environment Service (AES) of Canada sea ice/iceberg reconnaissance flights and other sources.

The IIP Operations Center received a total of 3156 sightings within its operations area (40°N - 52°N, 39°W - 57°W) and away from the Newfoundland coast in 1990 which were entered into IIP's drift model. For comparison IIP received 2986 during 1989. These sightings are broken down by type and sighting source in Table 1. The 3156 sightings entered into IIP's drift model represented only a fraction of the total sightings reported to IIP. Sightings of targets outside IIP's operations area or grounded or in areas of little or poorly defined current along the Newfoundland coast were not entered into the model.

Table 1 shows that IIP ICERECDETs and commer-

Table 1
Sightings entered into IIP's Drift Model

Sighting Source	Growler	Small	Medium	Large	Radar Target	Total	Percent of Total
Coast Guard (IIP)	270	295	381	126	68	1140	36.2
Commercial Ship	140	251	661	175	60	1287	40.8
Other Air Recon	66	218	92	32	0	408	12.9
DOD Sources	5	56	86	23	1	171	5.4
Canadian AES	18	62	19	7	29	136	4.3
BAPS	0	4	0	0	0	4	.1
Lighthouse/Shore	2	0	7	0	0	9	.3
Other	0	0	0	1	0	1	.0
Total	501	887	1246	364	158	3156	100.0

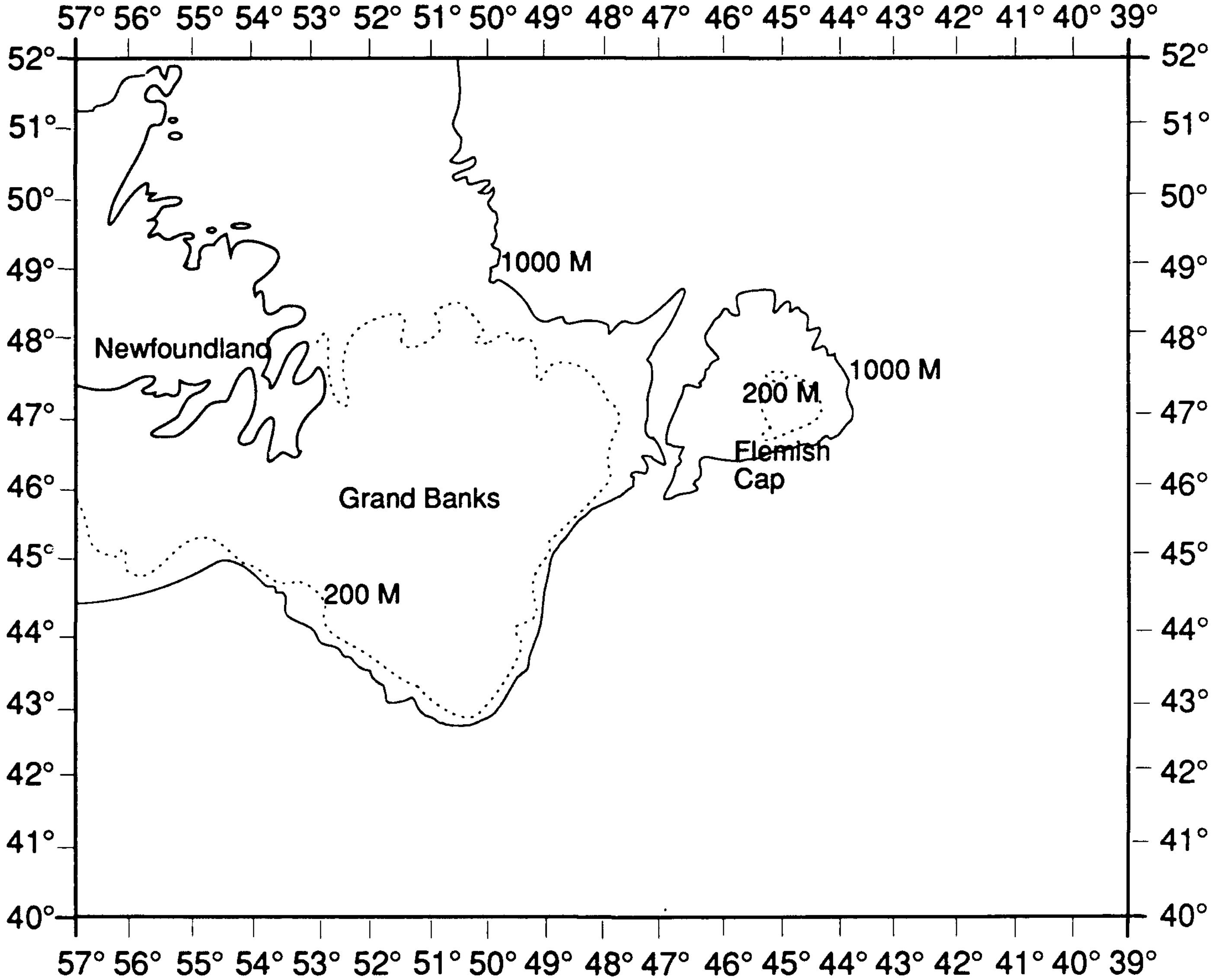


Figure 1. International Ice Patrol's Operation Area showing bathymetry of the Grand Banks of Newfoundland.

cial shipping were the major sources of iceberg sighting reports this season. AES of Canada was not able to provide as many reports this season as last. Appendix A lists all iceberg sighting reports, including reports of radar targets, received from commercial shipping, regardless of the sighting location. In Appendix A, a sighting report may represent several targets.

There is an apparent disparity between the number of sightings reported in 1990 and 1989 and the relative severity of the two seasons. Although 1990 was a much more severe season than 1989, the total sightings entered into the drift model were similar for the two years. This disparity is partly explained by cutbacks in AES Canada's iceberg flights in 1990 and, ironically, the severity of the 1990 season. The 1990 season was severe both in terms of the number of icebergs south of 48°N and the extreme southern extent of icebergs. Eight icebergs drifted south of 40°N (normally considered the southern boundary of IIP's operations area and the southern extent of IIP's computer model which predicts iceberg drift) during the year, and the southernmost berg sighted during the season was at 38-48°N, 47-19°W. Because of this severity, IIP had to devote most of its aerial patrols to surveys of the southern iceberg limits. Thus, IIP was unable to patrol the interior of the operating area, which normally contains the largest number and highest concentration of icebergs.

Table 2 compares the estimated number of icebergs crossing 48°N for each month of 1990 with the monthly mean number of icebergs crossing 48°N for each of the four reconnaissance eras. During the 1990 ice year, an estimated 793 icebergs drifted south of 48°N latitude, compared to 301 during 1989. The average number of icebergs drifting south of 48°N per year from 1900 to 1987 is 403 icebergs (Alfultis, 1987). IIP defines those ice years with less than 300 icebergs crossing 48°N as light ice years; those with 300 to 600 crossing 48°N as average; those with 600 to 900 crossing 48°N as heavy; and those with more than 900 crossing 48°N as extreme. Thus, 1990 was a heavy year.

IIP's computer model consists of one routine which

Table 2: Average Number of Icebergs South of 48°N - The four periods shown are pre-International Ice Patrol (1900-1912), ship reconnaissance (1913-45), aircraft visual reconnaissance (1946-82), and SLAR reconnaissance (1983-89).

	Avg 1900-12	Avg 1913-45	Avg 1946-82	Avg 1983-89	1990
OCT	2	2	0	1	0
NOV	1	3	0	2	0
DEC	3	1	0	2	0
JAN	2	3	2	2	0
FEB	6	11	7	37	9
MAR	69	36	32	82	112
APR	118	100	85	257	376
MAY	124	166	81	188	187
JUN	77	76	50	121	76
JUL	32	23	13	85	26
AUG	12	7	3	21	7
SEP	4	6	0	6	0
Era Average	450	434	273	804	793

predicts the drift of each iceberg and another which predicts the deterioration of each. The drift prediction program uses a historical current file which is modified weekly using satellite-tracked ocean drifting buoy data, thus taking into account local, short-term, current fluctuations. Murphy and Anderson (1985) describe and evaluate the IIP drift model.

The IIP iceberg deterioration program uses daily sea surface temperature and wave height information from the U.S. Navy Fleet Numerical Oceanography Center (FNOC) to predict the melt of icebergs. Anderson (1983) and Hanson (1987) describe the IIP deterioration model in detail. It is the combined ability of the SLAR to detect icebergs in all weather and IIP's computer models to estimate iceberg drift and deterioration which enables IIP to schedule aerial iceberg surveys every other week rather than every week.

Ten satellite-tracked ocean drifting buoys were deployed to provide operational data for IIP's iceberg drift model. Five buoys were the standard size drifting buoys IIP has been deploying for fifteen years. The other five were smaller drifting buoys which IIP evaluated during an oceanographic cruise and then deployed operationally from the cruise vessel. All buoys were equipped with temperature sensors, and two of the standard buoys were also equipped with barometric pressure sensors. The U.S. Naval Oceanographic Command provided the funding for these barometric sensors. Drift data from the buoys are discussed in Appendix B.

During the 1990 season, IIP operationally deployed 35 Air-deployable eXpendable BathyThermograph (AXBTs). The AXBT measures temperature with depth and transmits the data back to the aircraft. Temperature data from the AXBTs were sent to the Canadian Meteorological and Oceanographic Center (METOC) in Halifax, Nova Scotia, Canada, the U.S. Naval Eastern Oceanography Center (NEOC) in Norfolk, Virginia, and FNOC for use as inputs into ocean temperature models. IIP directly benefits from its AXBT deployments by having improved ocean temperature data provided to its iceberg deterioration model. To further enhance the quality of environmental data used in its iceberg models, IIP also provided weekly drifting buoy sea surface temperature (SST) and drift histories and SLAR ocean feature analyses to METOC and NEOC for use in water mass and SST analyses.

IIP conducted an oceanographic cruise aboard the USCGC SPAR (WLB 403) between 8 and 23 June 1990 off the Grand Banks of Newfoundland. The objectives of the cruise were: 1) to conduct an operational evaluation of mini-TOD's for use as current-measuring devices, and 2) to determine the drift errors of the full-sized TOD's IIP uses. The results will be published in a U. S. Coast Guard Research Development Center Technical or IIP Technical Report.

On April 13, 1990, IIP paused to remember the 78th anniversary of the sinking of the RMS TITANIC. During an ice reconnaissance patrol, two memorial wreaths were placed near the site of the sinking to commemorate the nearly 1500 lives lost.

Iceberg Reconnaissance and Communications

During the 1990 Ice Patrol year, 96 aircraft sorties were flown in support of IIP, 43 for transit to St. John's, Newfoundland and 53 for ice observation. The ice observation flights were made to locate the southwestern, southern, and southeastern limits of icebergs. In addition 6 logistics flights were necessary to support and maintain the patrol aircraft. Tables 3 and 4 show aircraft use during the 1990 ice year.

Aerial ice reconnaissance was conducted with SLAR-equipped U. S. Coast Guard HC-130H and HU-25B aircraft. The HC-130H aircraft deployed from Coast Guard Air Station Elizabeth City, North Carolina, and HU-25B aircraft deployed from Coast Guard Air Station Cape Cod, Massachusetts.

The HC-130 'Hercules' aircraft has been the platform for Ice Patrol aerial reconnaissance since 1963. This was the third year for the HU-25B to serve as an Ice Patrol platform. Although the HU-25B does not have the range of the HC-130, it can serve as an excellent complement and is normally capable of covering a majority of the IIP operations area.

Table 3. AIRCRAFT USED DURING THE 1990 IIP YEAR.

Aircraft	HU-25B		HC-130		Total	
Deployment	Sorties	Flight Hours	Sorties	Flight Hours	Sorties	Flight Hours
Pre Seson	0	0	0	0	0	0
Regular Season	39	93.0	57	259.5	96	352.5
Ice Recon	23	70.1	30	186.5	53	256.6
Transit	16	22.9	27	73.0	43	95.9
Post Season	0	0	0	0	0	0
Totals	39	93.0	57	259.5	96	352.5

Each day during the ice season, IIP prepares the 0000Z and 1200Z ice bulletins warning mariners of the southwestern, southern, and southeastern limits of icebergs. U.S. Coast Guard Communications Station Boston, Massachusetts, NMF/NIK, and Canadian Coast Guard Radio Station St. John's Newfoundland/VON were the primary radio stations responsible for the dissemination of the ice bulletins. Other transmitting stations for the bulletins included Canadian Forces Meteorological and Oceanographic Center (METOC) Halifax, Nova Scotia/CFH and U.S. Navy LCMP Broadcast Stations Norfolk/NAM, Thurso, Scotland; Keflavik, Iceland; Key West, Florida; and Rota, Spain.

IIP also prepares a daily facsimile chart graphically depicting the limits of all known ice for broadcast at 1600Z. U. S. Coast Guard Communications Station Boston assisted with the transmission of these charts. Canadian Forces METOC, Halifax/CFH, and AM Radio Station Bracknell/GFE, United Kingdom used Ice Patrol limits in their broadcasts. Canadian Coast Guard Radio Station St. John's/ VON and U.S. Coast Guard Communications Station Boston / NIK provided special broadcasts.

The International Ice Patrol requested that all ships transiting the area of the Grand Banks report ice sightings, weather, and sea surface temperatures via Canadian Coast Guard Radio Station St. John's/VON or U. S. Coast Guard Communications Station Boston/NIK. Response to this request is shown in Table 5. Appendix A lists all contributors. IIP received relayed information from the following sources during the 1990 ice year: St. John's VON; ECAREG Halifax, Canada; U.S. Coast Guard Communications and Master Station Atlantic, Chesapeake, Virginia; and U.S. Coast Guard Automated Merchant Vessel Emergency Response/Operational Computer Center, New York. Commander, International Ice Patrol extends a sincere thank you to all stations and ships which contributed.

TABLE 4. ICEBERG RECONNAISSANCE SORTIES BY MONTH

	HU-25B		HC-130		TOTAL	
MONTH	**SORTIES**	**FLIGHT HOURS**	**SORTIES**	**FLIGHT HOURS**	**SORTIES**	**FLIGHT HOURS**
JAN	0	0	0	0	0	0
FEB	0	0	0	0	0	0
MAR	8	25.6	5	30.0	13	55.6
APR	4	12.8	5	25.8	9	38.6
MAY	0	0	8	61.1	8	61.1
JUN	0	0	9	52.2	9	52.2
JUL	6	18.2	3	17.4	9	35.6
AUG	5	13.5	0	0	5	13.5
TOTAL	23	70.1	30	186.5	53	256.6

Table 5
Iceberg and SST Reports

Number of ships furnishing Sea Surface Temperature (SST) reports	88
Number of SST reports received	344
Number of ships furnishing ice reports	480
Number of ice reports received	1294
First Ice Bulletin	090000Z MAR 90
Last Ice Bulletin	151200Z AUG 90
Number of facsimile charts transmitted	159

DISCUSSION OF ICE AND ENVIRONMENTAL CONDITIONS

Since more than 10,000 icebergs are calved by Greenland's glaciers into the Baffin Bay each year (Knutson and Neill, 1978), annual fluctuations in the generation of Arctic icebergs are not a significant factor influencing the number of icebergs passing south of 48° N annually. Rather than the supply of icebergs available to drift south to the vicinity of the Grand Banks, the factors that most determine the number of icebergs passing south of 48° N each season are those affecting iceberg transport (currents, winds, and sea ice) and the rate of iceberg deterioration (wave action, sea surface temperature, and sea ice).

The wind direction along the Labrador and Newfoundland coasts can affect the iceberg severity of each ice year since the mean wind flow can influence iceberg drift. Dependent upon wind intensity and duration, icebergs can be accelerated along or driven out of the main flow of the Labrador Current (Figure 2). Departure from the Labrador Current normally slows their southerly drift and, in many cases, speeds up their rate of deterioration.

The wind direction and air temperature indirectly affect the iceberg severity of each ice year by influencing the extent of sea ice. Sea ice protects the icebergs from wave action, the major agent of iceberg deterioration. If the air temperature and wind direction are favorable for the sea ice to extend to the south and over the Grand Banks of Newfoundland, the icebergs will be protected longer as they drift south. When the sea ice retreats in the spring, large numbers of icebergs will be left behind on the Grand Banks. Also, if the time of sea ice retreat is delayed by below normal air temperatures, the icebergs will be protected longer, and a longer than normal ice season can be expected. The opposite is true if the southerly sea ice extent is minimal, or if above normal air temperatures cause an early retreat of sea ice from the Grand Banks.

Sea ice also acts to impede the transport of icebergs by winds and currents. The degree to which an iceberg drift is affected depends on the concentration of the sea ice and the size of the iceberg. The greater the sea ice concentration the greater the affect on iceberg drift. The larger the iceberg the less affected its drift is by sea ice. Although it slows current and wind transport of icebergs, sea ice is itself an active medium, continually moving toward the ice edge where melt occurs. Icebergs in sea ice will eventually reach open water unless grounded. The melting of sea ice is affected by snow cover (which slows melting) and air and sea water temperatures. As sea ice melt accelerates in the spring and early summer, trapped icebergs are rapidly released and then become subject to normal transport and deterioration.

The Labrador Current, aided by northwesterly winds in winter, is the main mechanism transporting icebergs south to the Grand Banks. In addition to transporting icebergs south, the relatively cold water of the Labrador Current keeps the deterioration of icebergs in transit to a minimum.

The following discussion summarizes environmental, sea ice, and iceberg conditions along the Labrador and Newfoundland coasts and on the Grand Banks of Newfoundland for the 1990 ice year. The sea ice information was derived from the Thirty Day Ice Forecast for Northern Canadian Waters published monthly by Ice Centre Ottawa, Atmospheric Environment Service (AES) of

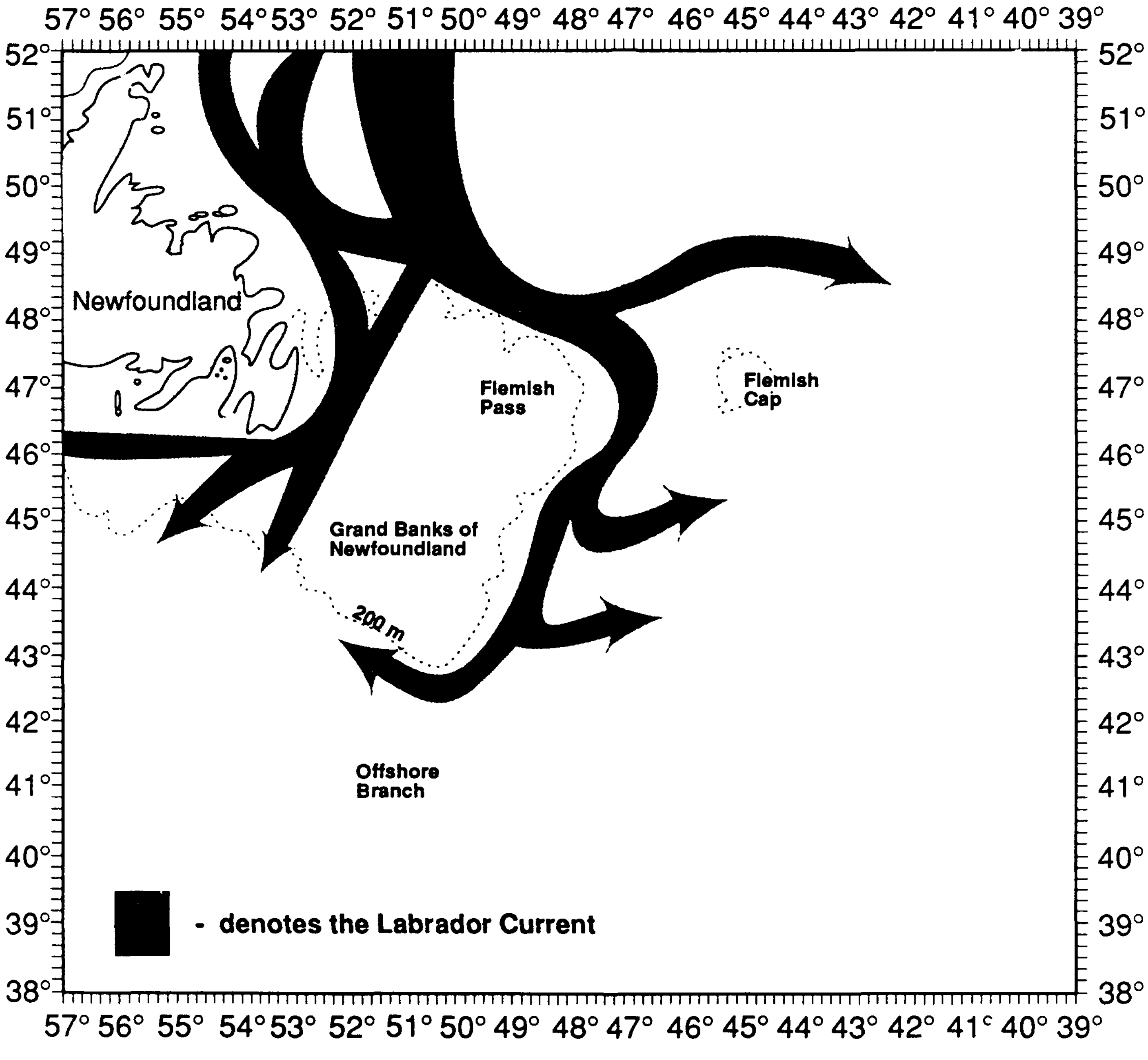


Figure 2: This figure depicts the Labrador Current, the main mechanism for transporting icebergs South to the Grand Banks.

Canada, and information on the mean sea ice extent was obtained from Ice Limits Eastern Canadian Seaboard, Ice Centre Ottawa, Atmospheric Environment Service, 1989. Figures 3 to 14 compare sea ice extents during the 1990 IIP year to mean sea ice extents. Environmental information was obtained from the Mariner's Weather Log and AES Thirty Day Ice Forecasts.

During January, February, and March 1990 the Icelandic Low was significantly lower (up to 27 mb

lower in February) than normal. Temperatures were about 2°C below normal, and winds were from the west/northwest over the Newfoundland coast. The wind direction and colder temperatures resulted in the sea ice extent being much greater than normal to the south and east during January, February, and March. Figure 8 shows the sea ice extent on 12 March 1990 compared to the mean sea ice edge. There were 8 new bergs south of 48°N in February, the first month with bergs in the IIP area, and 113 south of 48°N in March.

The greater than normal sea ice conditions during the first part of the ice season protected icebergs from deterioration longer. Furthermore, when the ice edge receded to the north in April (the ice edge receded over 500 km between mid-March and mid-April) a large number of icebergs were released farther south than normal. There were 376 new bergs south of 48°N in April. From mid-April to mid-June (Figures 9,10, and 11) the southern edge of the sea ice remained at about 51°N, just inside the IIP area, and its extent was still greater than normal. During May, the IIP Limits of All Known Ice extended south of 40°N, the IIP southern boundary. This extreme southern limit of bergs was probably influenced by the extreme southern extent and late retreat of the sea ice. Furthermore, sea surface temperature (SST) charts show that the North Atlantic Current made a southward meander in the region south of the Grand Banks (approximately 40°N, 50°W) during the latter half of May. This permitted a tongue of the colder (less than 6°C) Labrador Current to extend farther south than normal. From 15-25 May, the Labrador Current, the main mechanism for transporting icebergs southward, extended below 39°N before receding to the north. This tongue of colder water undoubtedly was the primary reason for the extreme southern iceberg extent during May. Eight bergs were predicted to drift south of 40°N during May by IIP's computer model, and the southernmost berg sighted during the season was at 38.8°N, 47.3°W on 26 May 1990. Because IIP's computer model was not able to drift bergs south of 40°N, IIP increased aerial reconnaissance of the southern Limits of All Known Ice during this period of extreme iceberg extent. IIP also drew larger than standard error circles around the bergs south of 40°N and expanded the error circles daily to a maximum of 45 miles from the last sighted or predicted berg position after four days on plot. Figures 15 -26 show the IIP Limits of All Known Ice and the sea ice edge for the 15th and 30th of each month of the ice season.

During June the southern berg extent began to decrease, and between 30 May and 15 June the IIP Limit of All Known Ice receded about 500 km to the north. Under the influence of southwesterly winds the sea ice finally departed the IIP area in mid-June, and by mid-July there was no sea ice south of 57°N.

In summary, 1990 was a heavy ice year in terms of the number of bergs south of 48°N and uncommonly severe in terms of the southern extent of bergs. This probably resulted from the greater than normal sea ice extent protecting the bergs longer and releasing them farther south in IIP's area and the anomalous Labrador Current flow which transported the bergs to extreme southern extents.

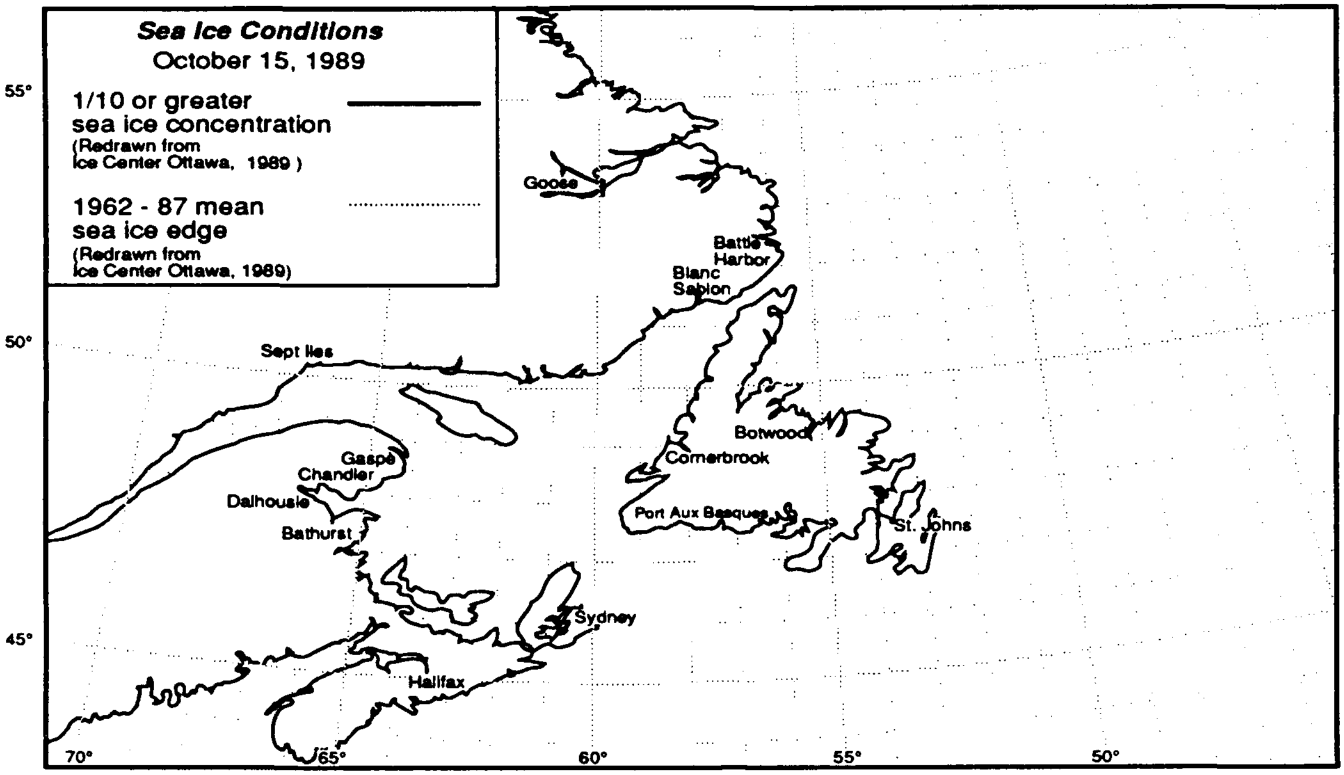
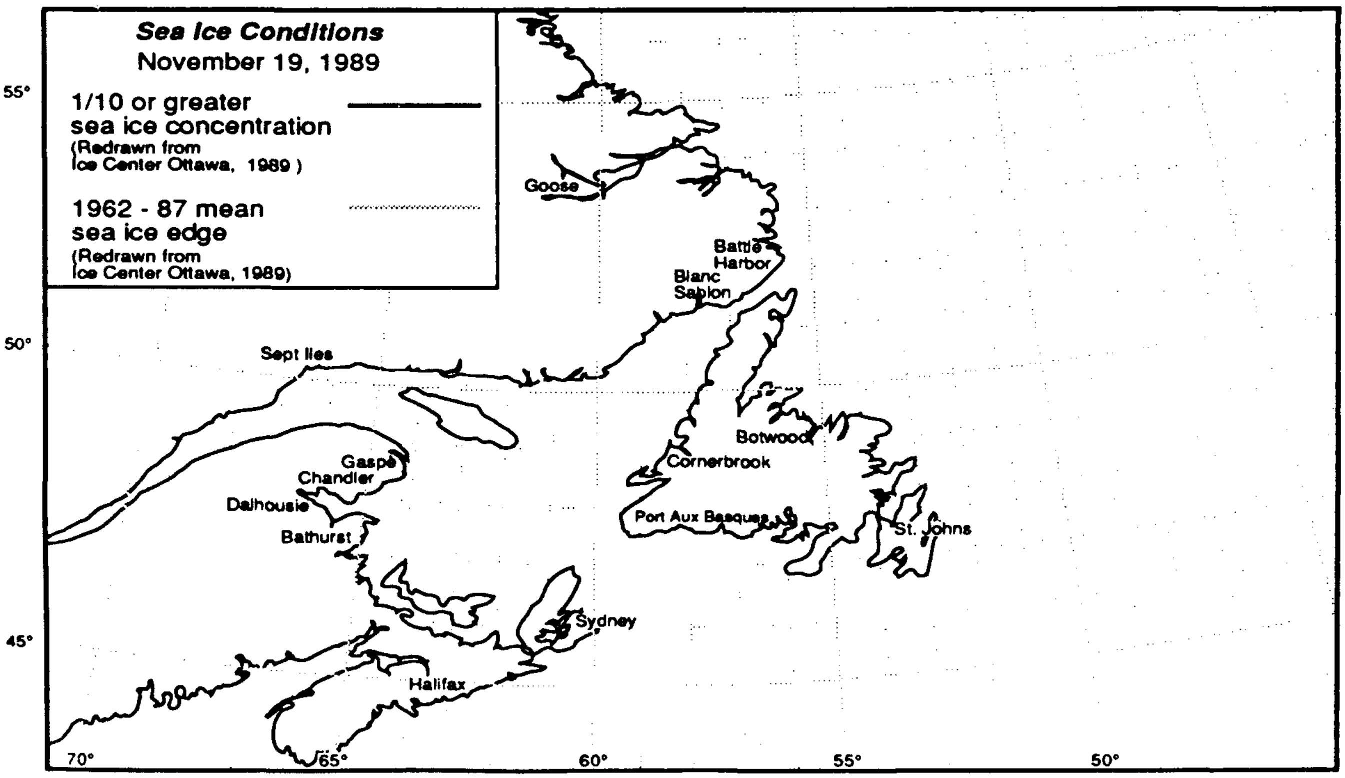


Figure 3



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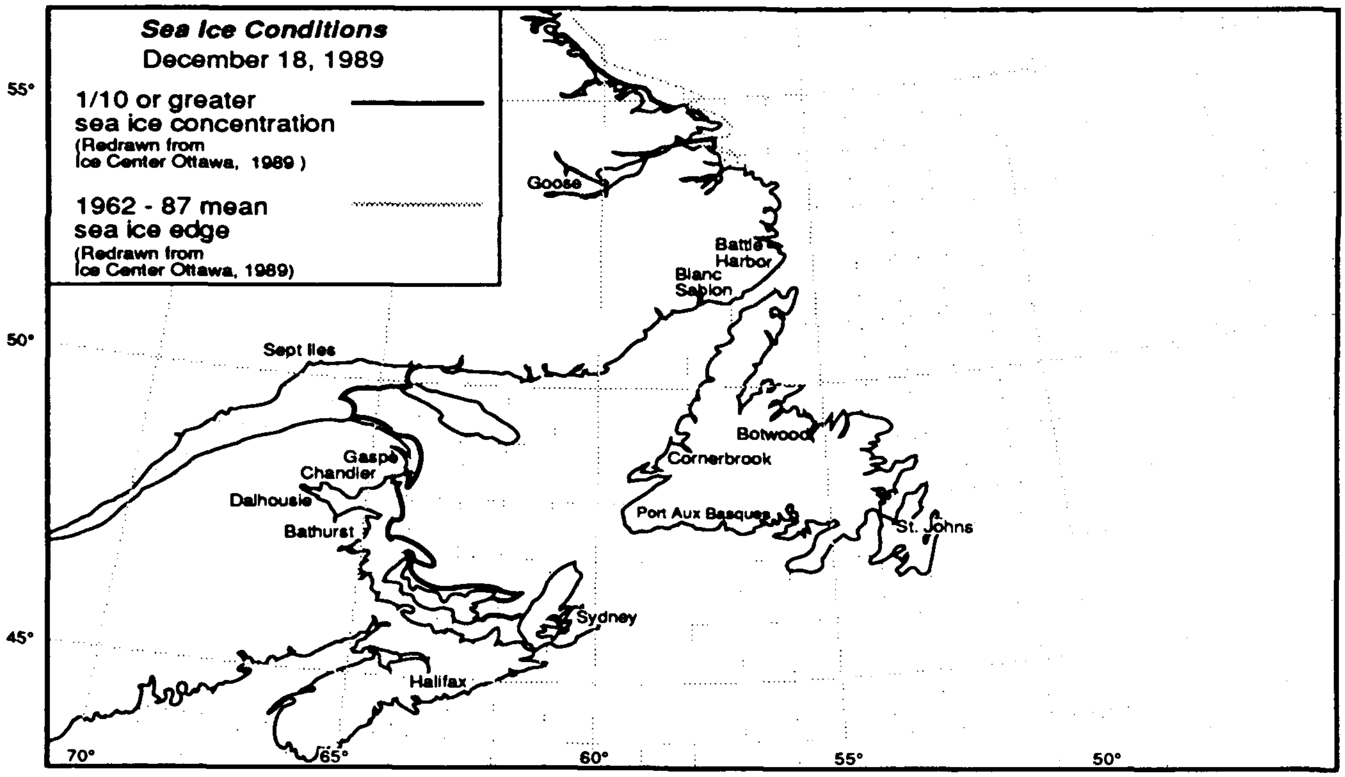

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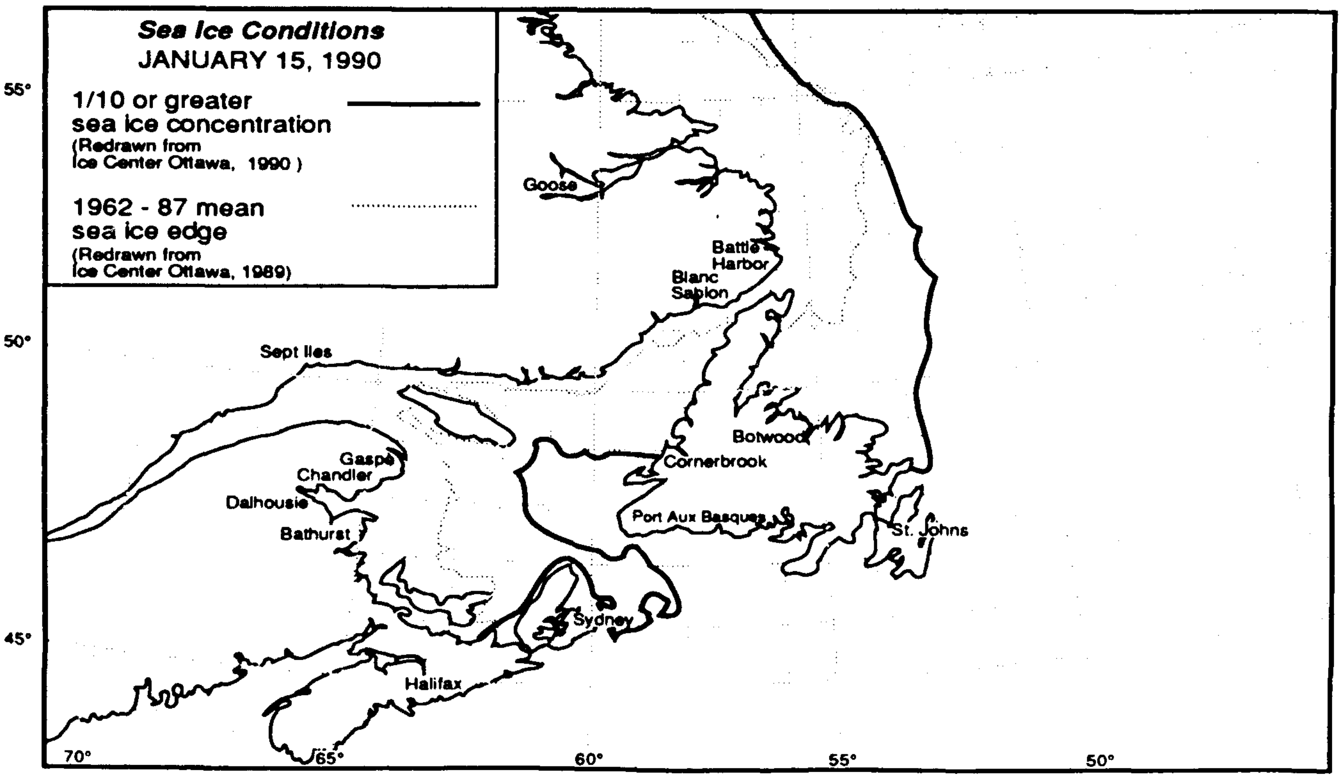

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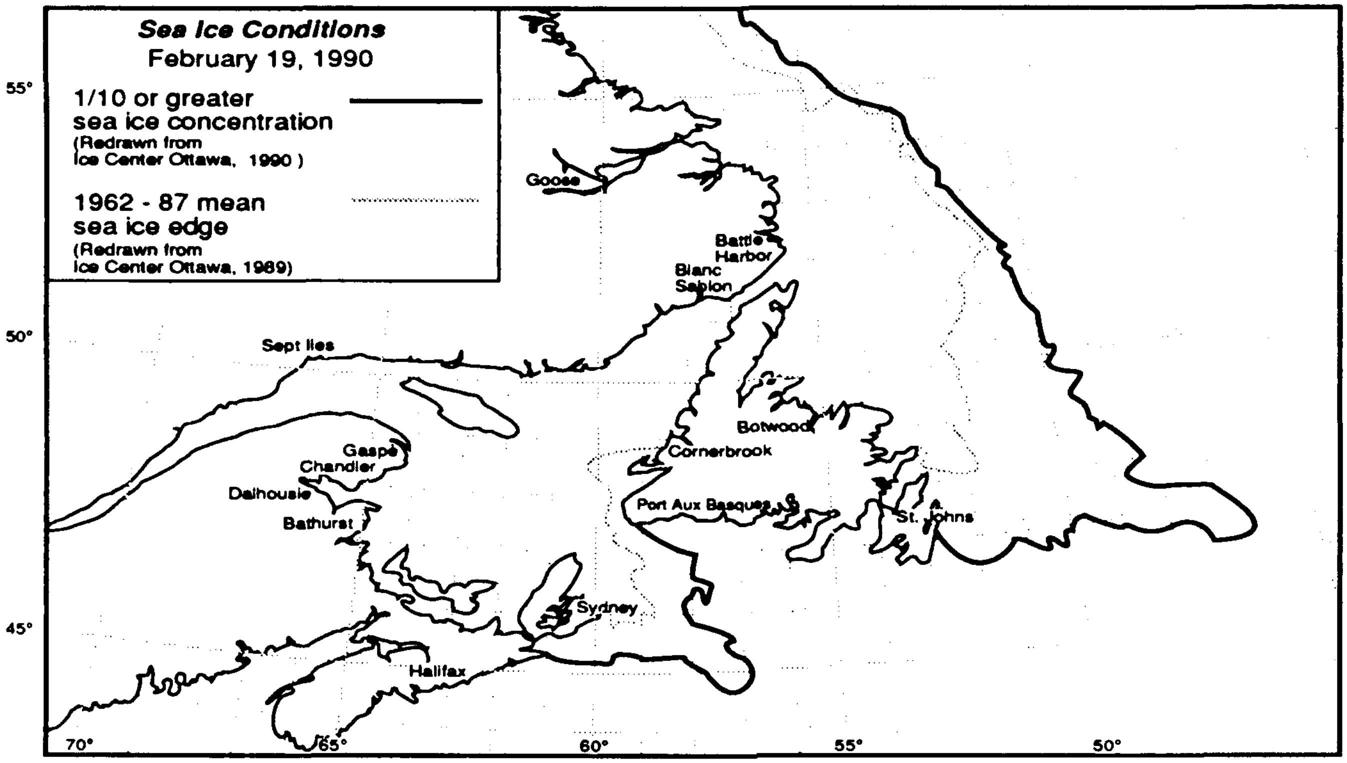

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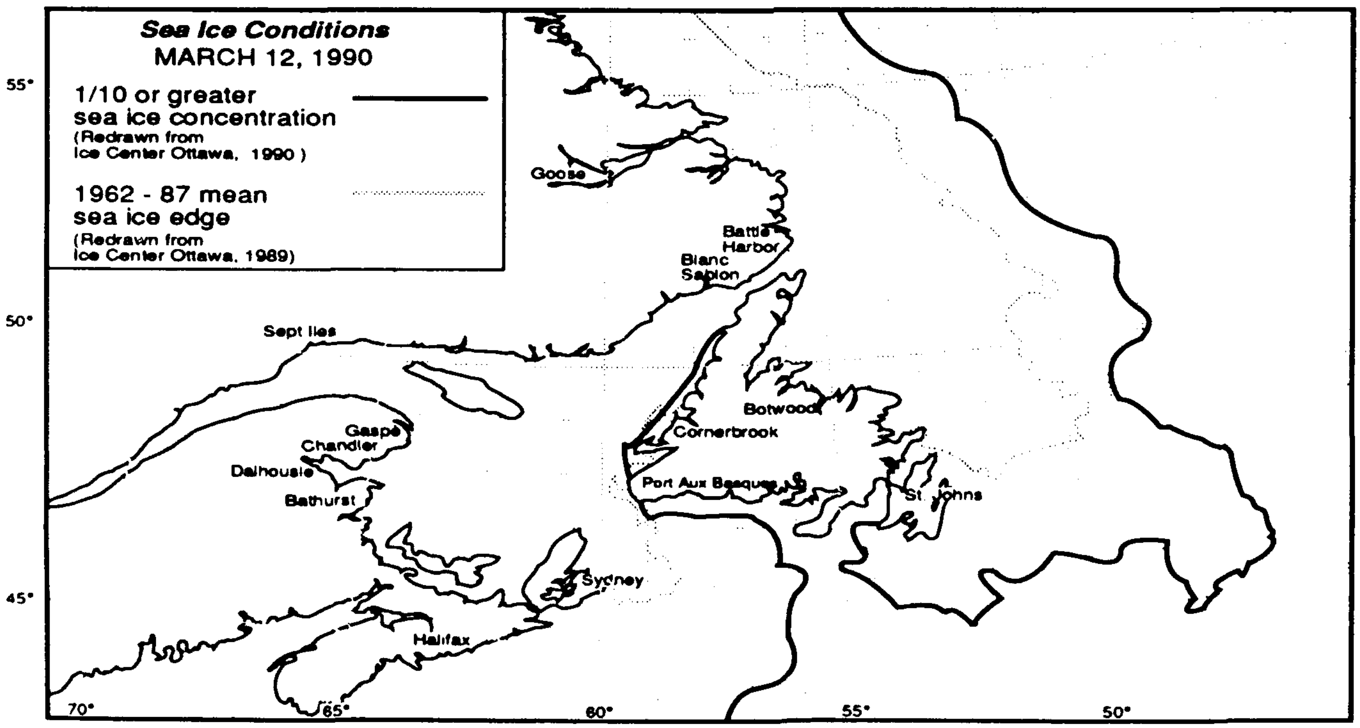
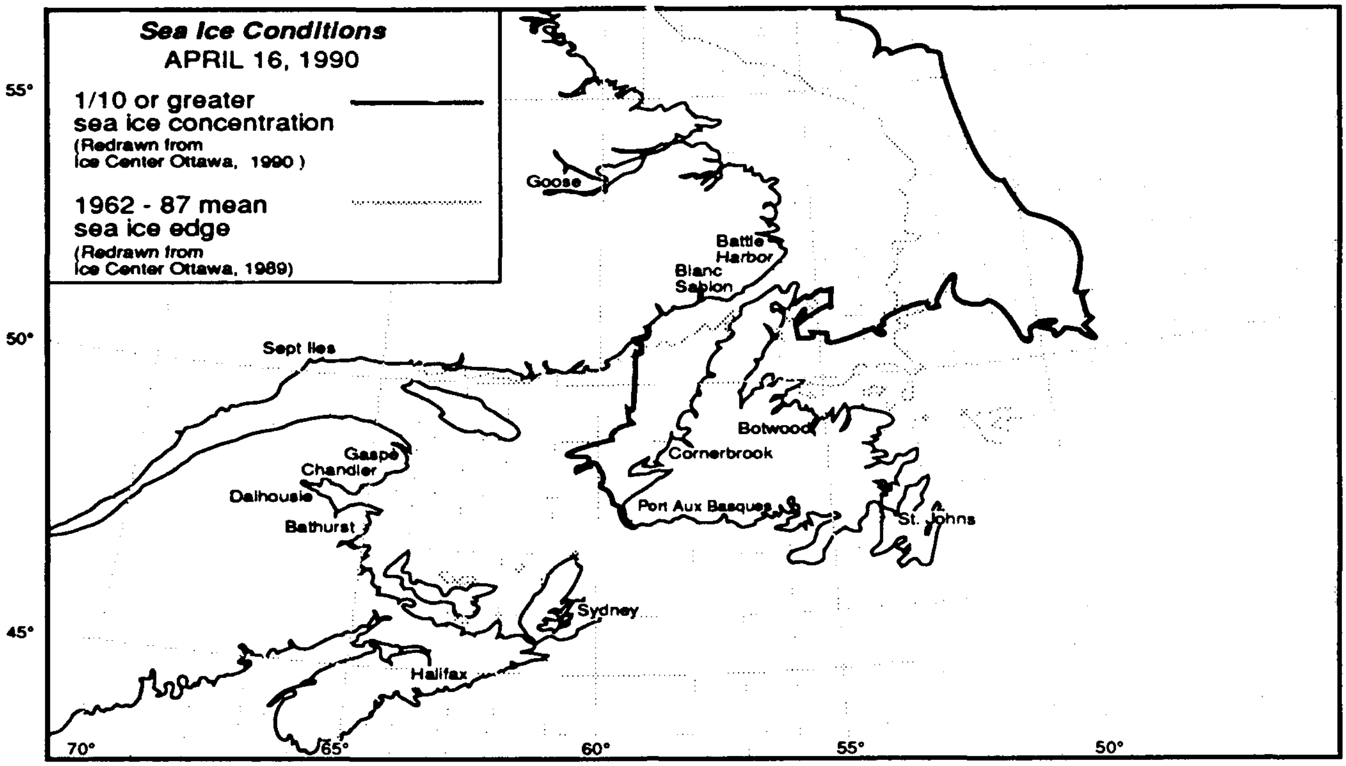


Figure 8



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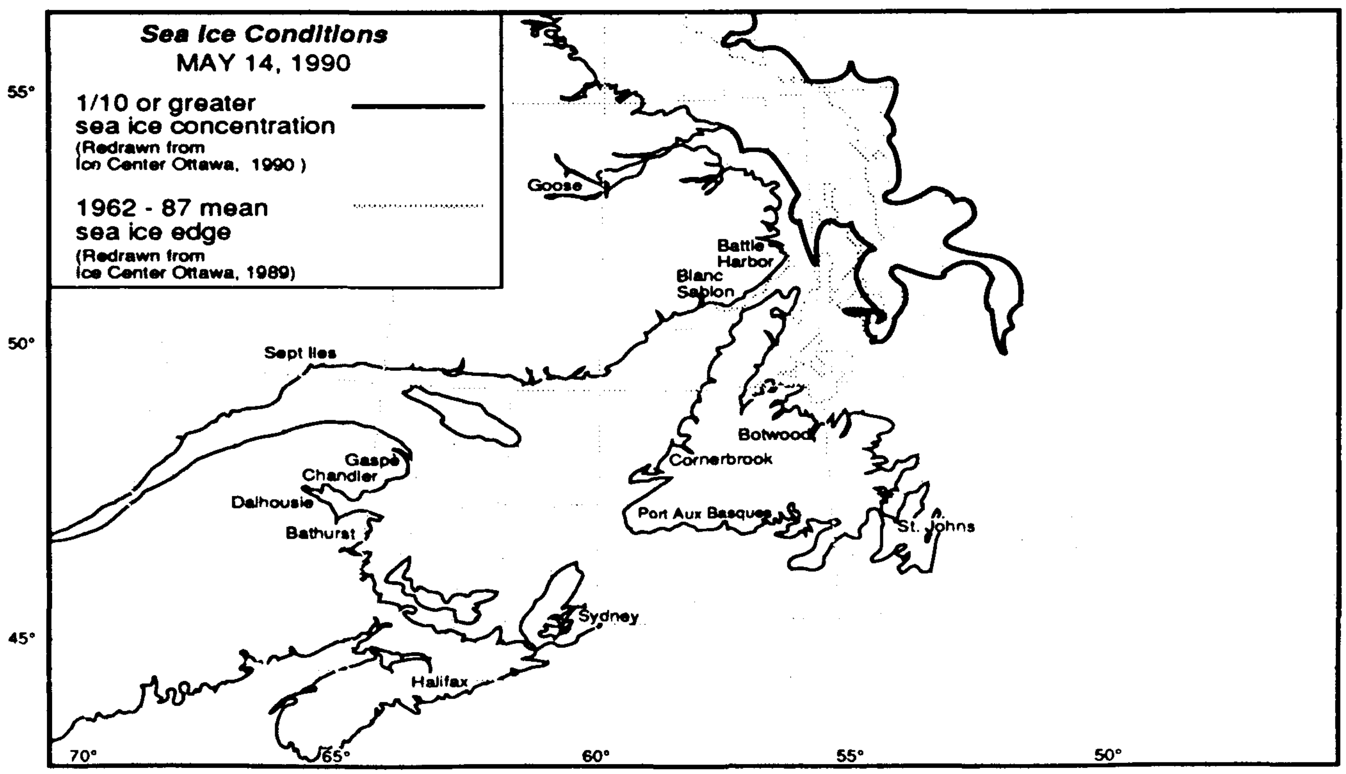

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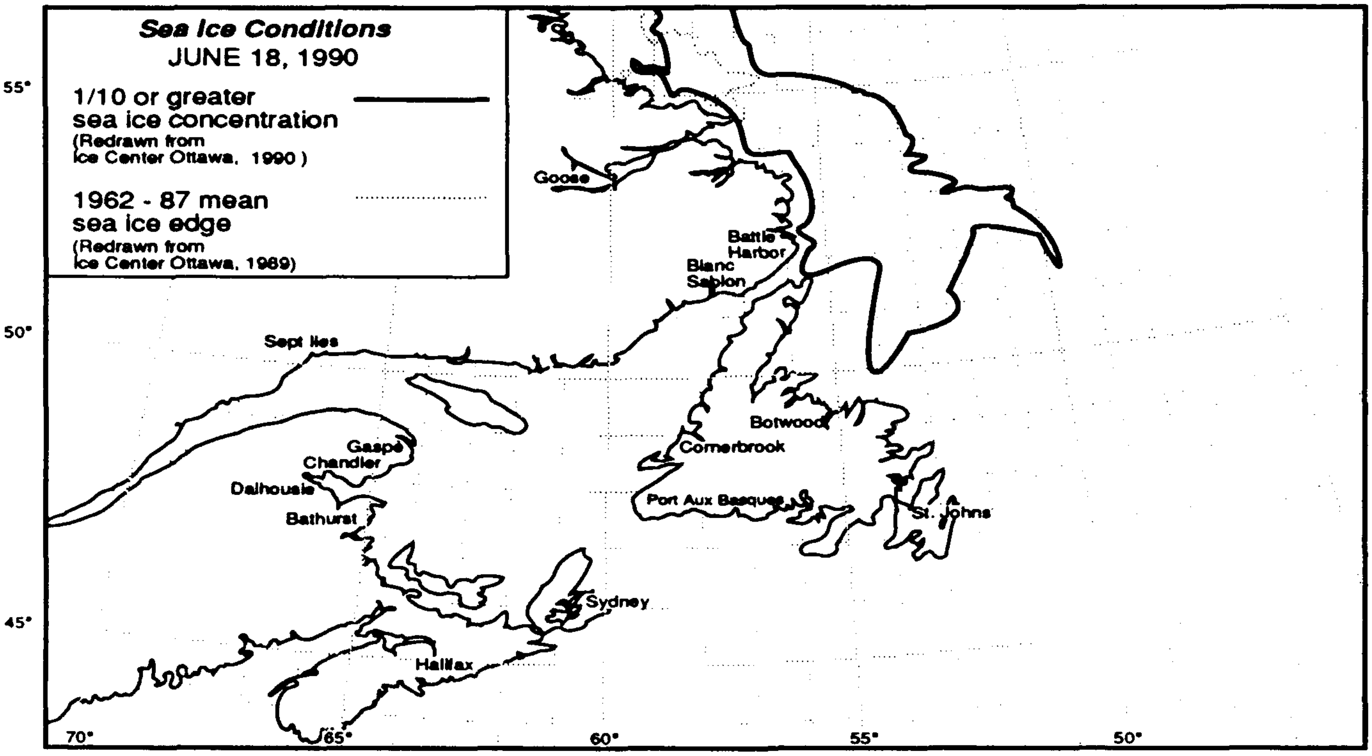

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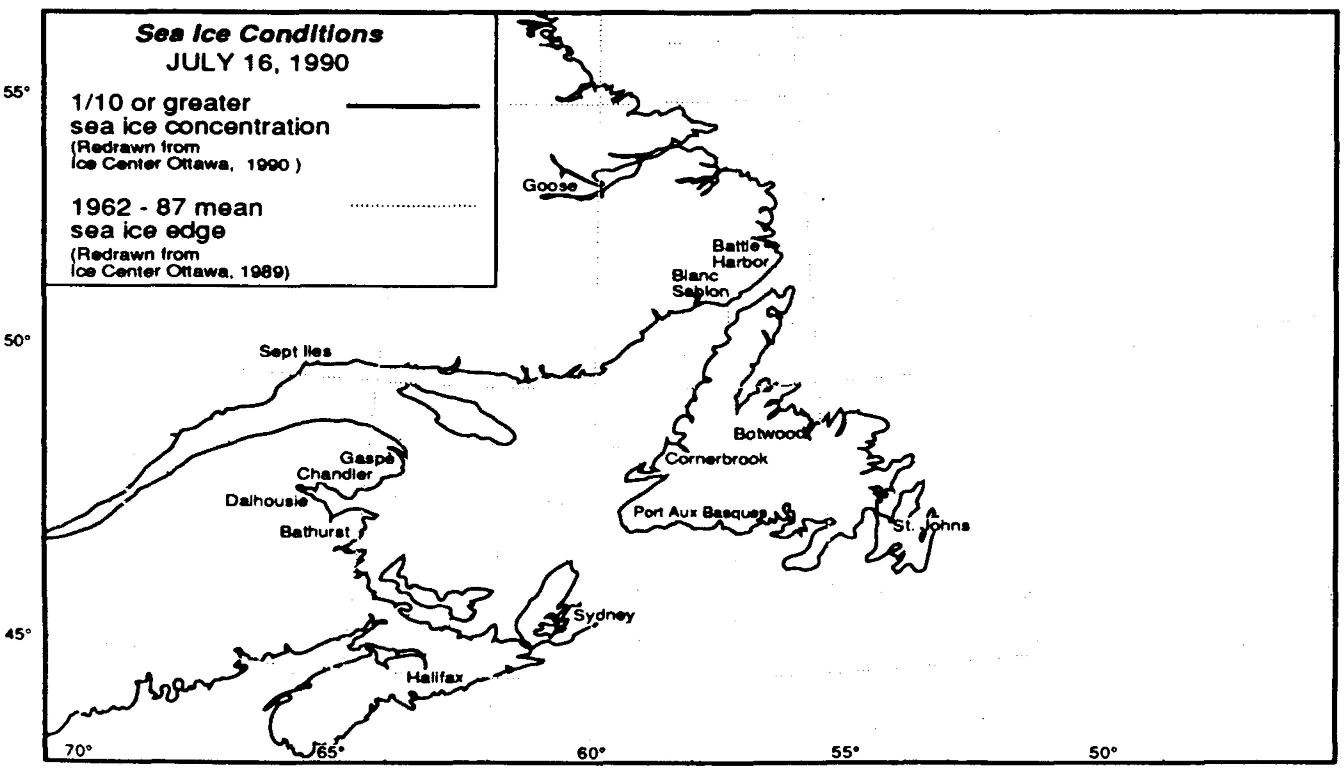

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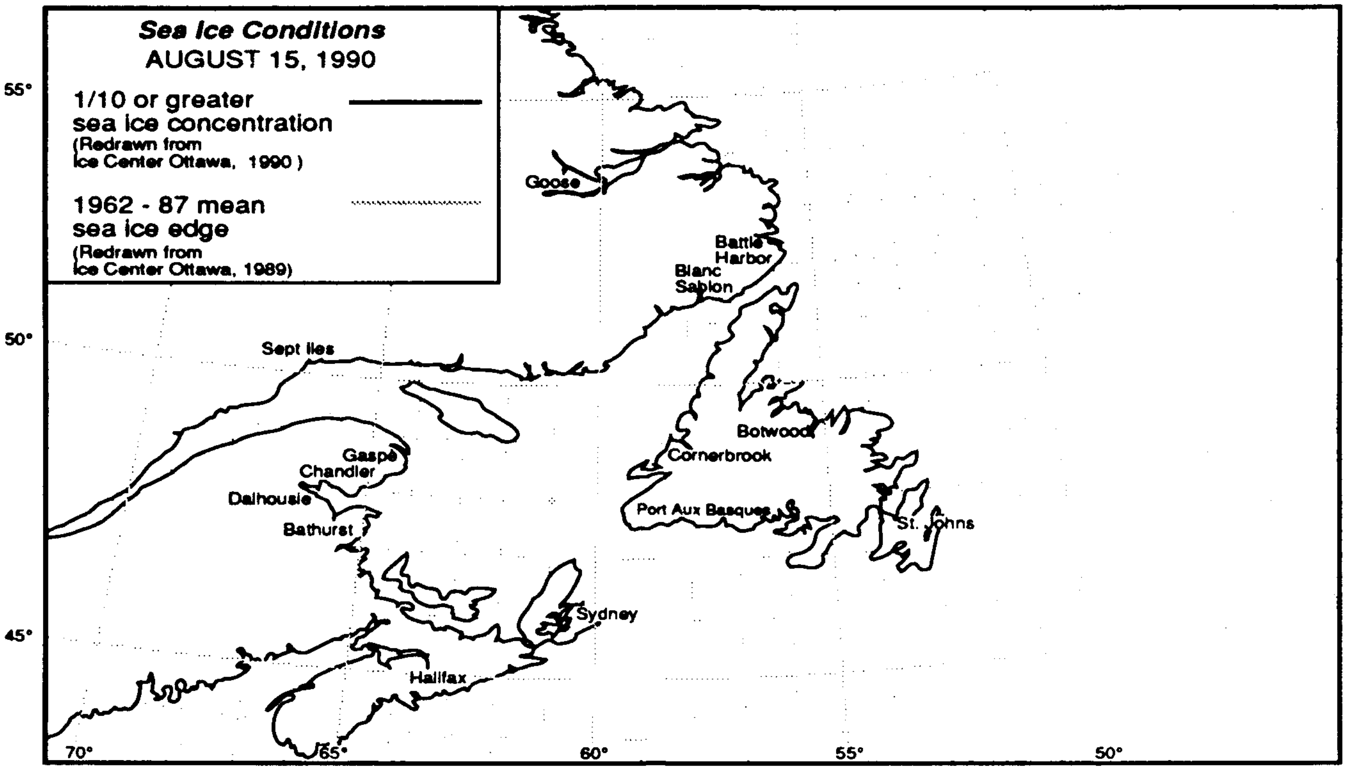

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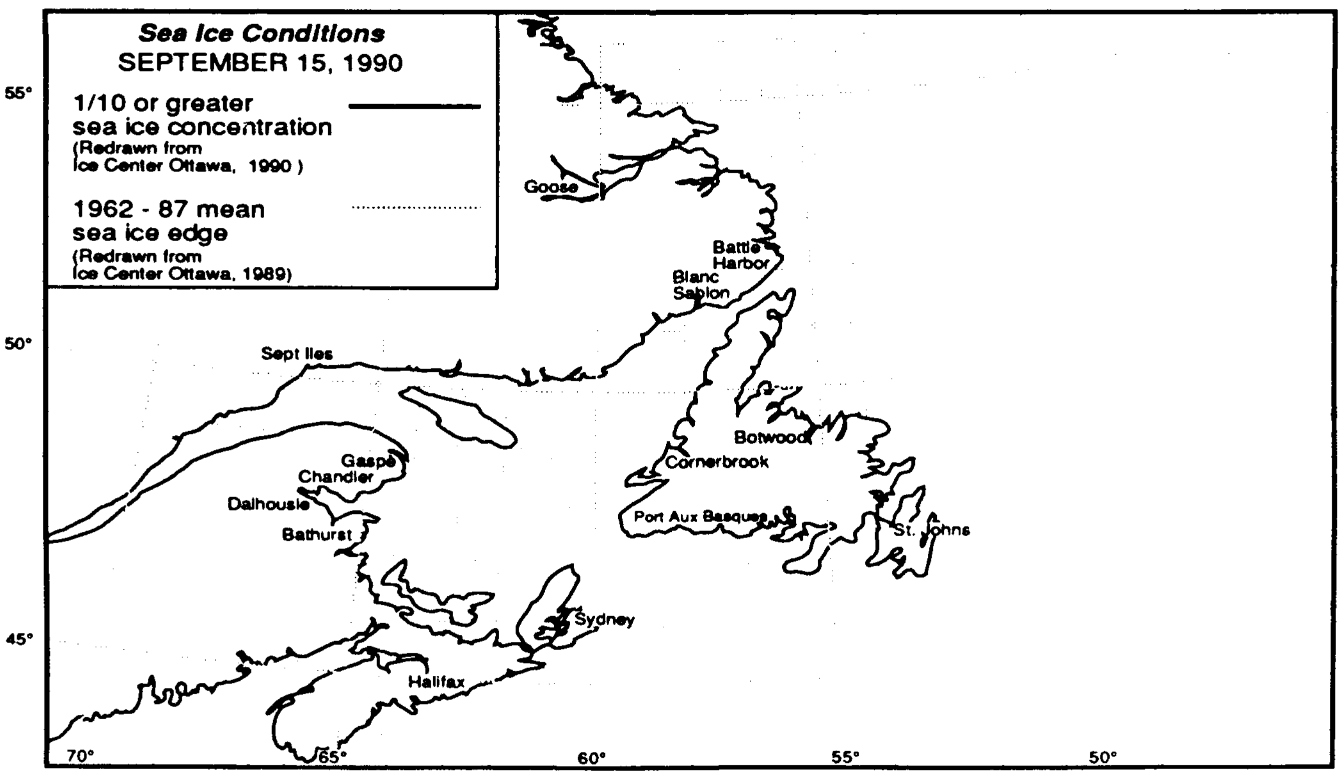


Figure 14

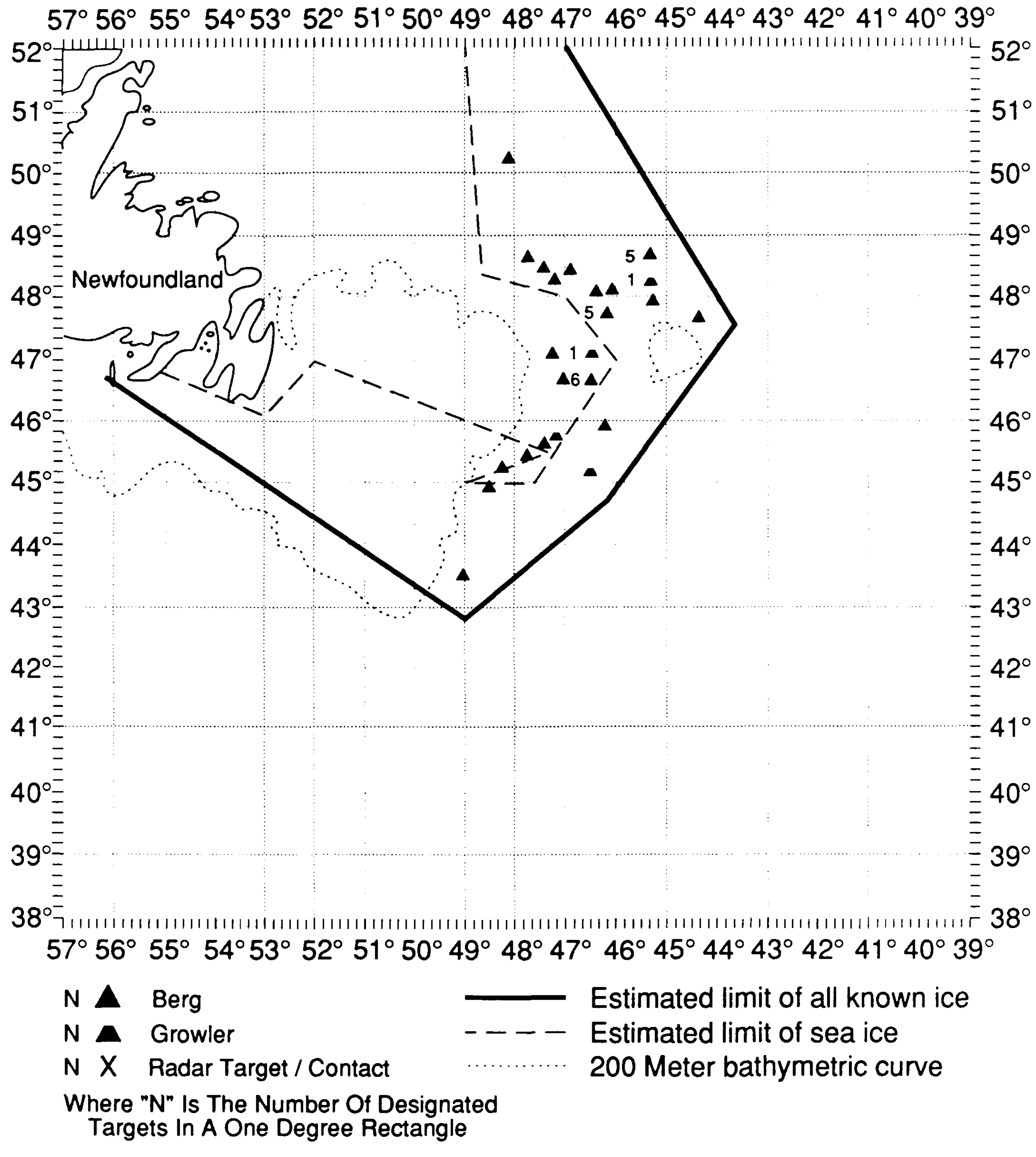


Figure 15. Graphic Depiction Of International Ice Patrol Ice Plot
For 1200 GMT 09MAR90 Based On Observed And Forecast Conditions

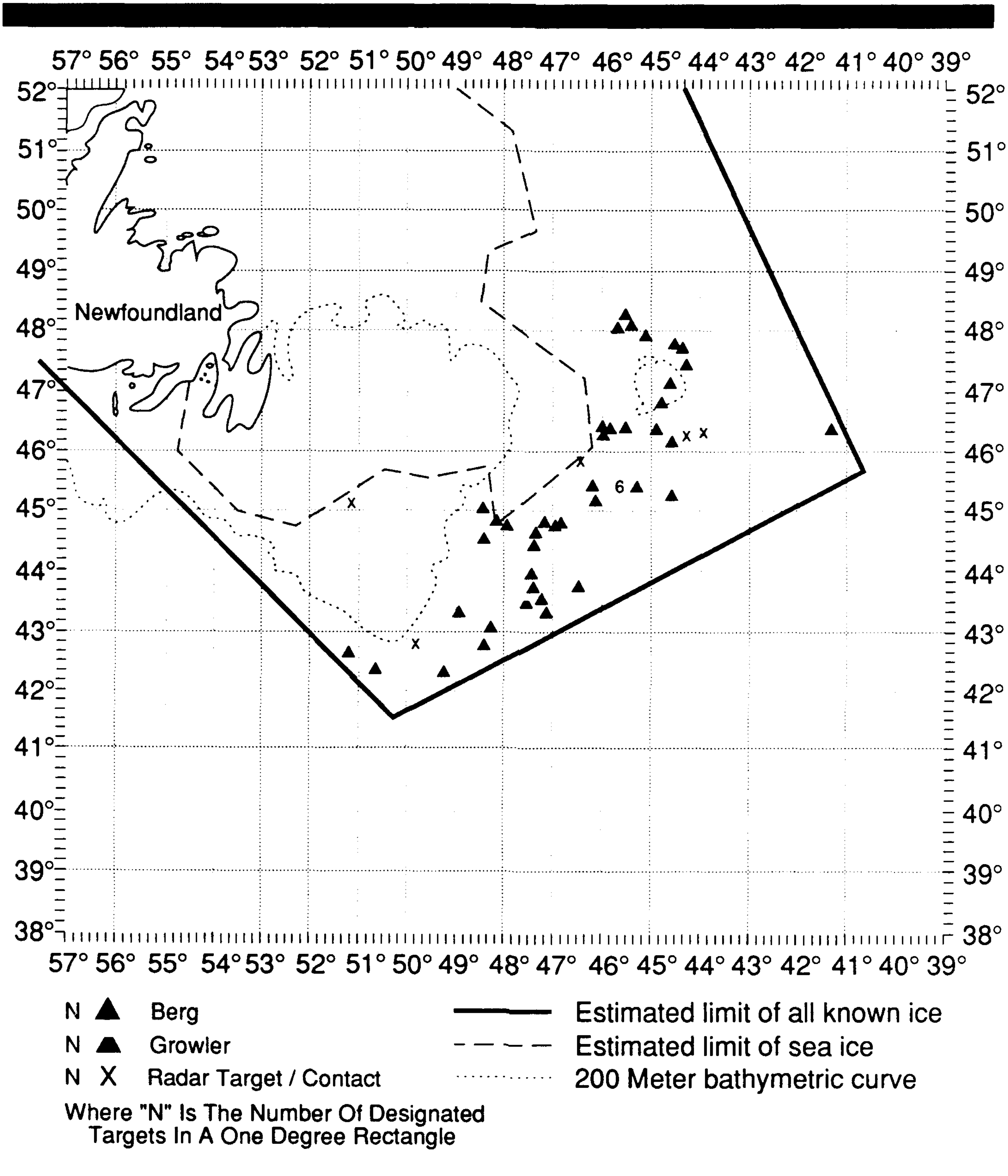
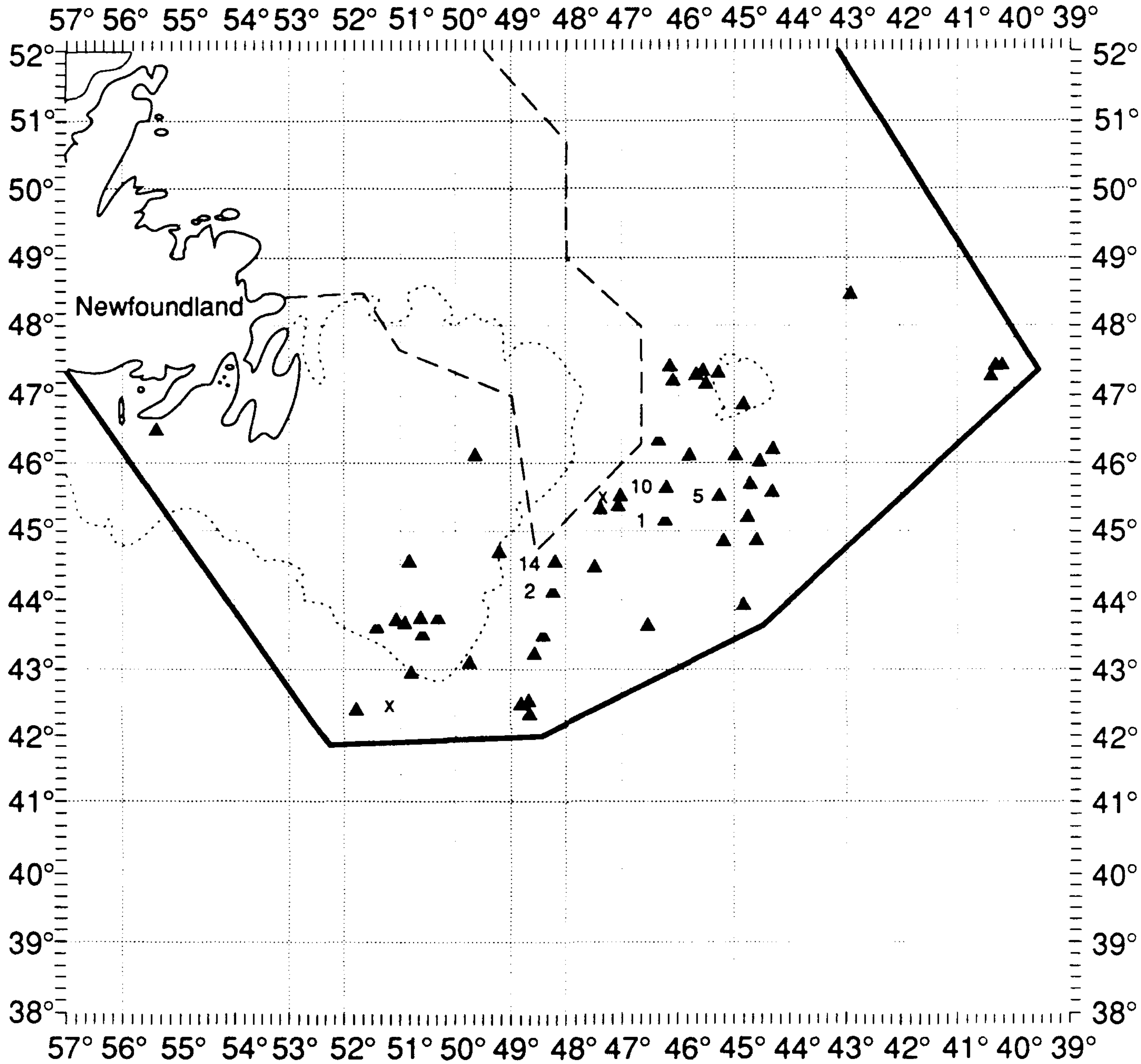


Figure 16. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15MAR90 Based On Observed And Forecast Conditions



N ▲ Berg
N ▲ Growler
N X Radar Target / Contact
Where "N" Is The Number Of Designated Targets In A One Degree Rectangle

——— Estimated limit of all known ice
– – – – Estimated limit of sea ice
········ 200 Meter bathymetric curve

Figure 17. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 30MAR90 Based On Observed And Forecast Conditions

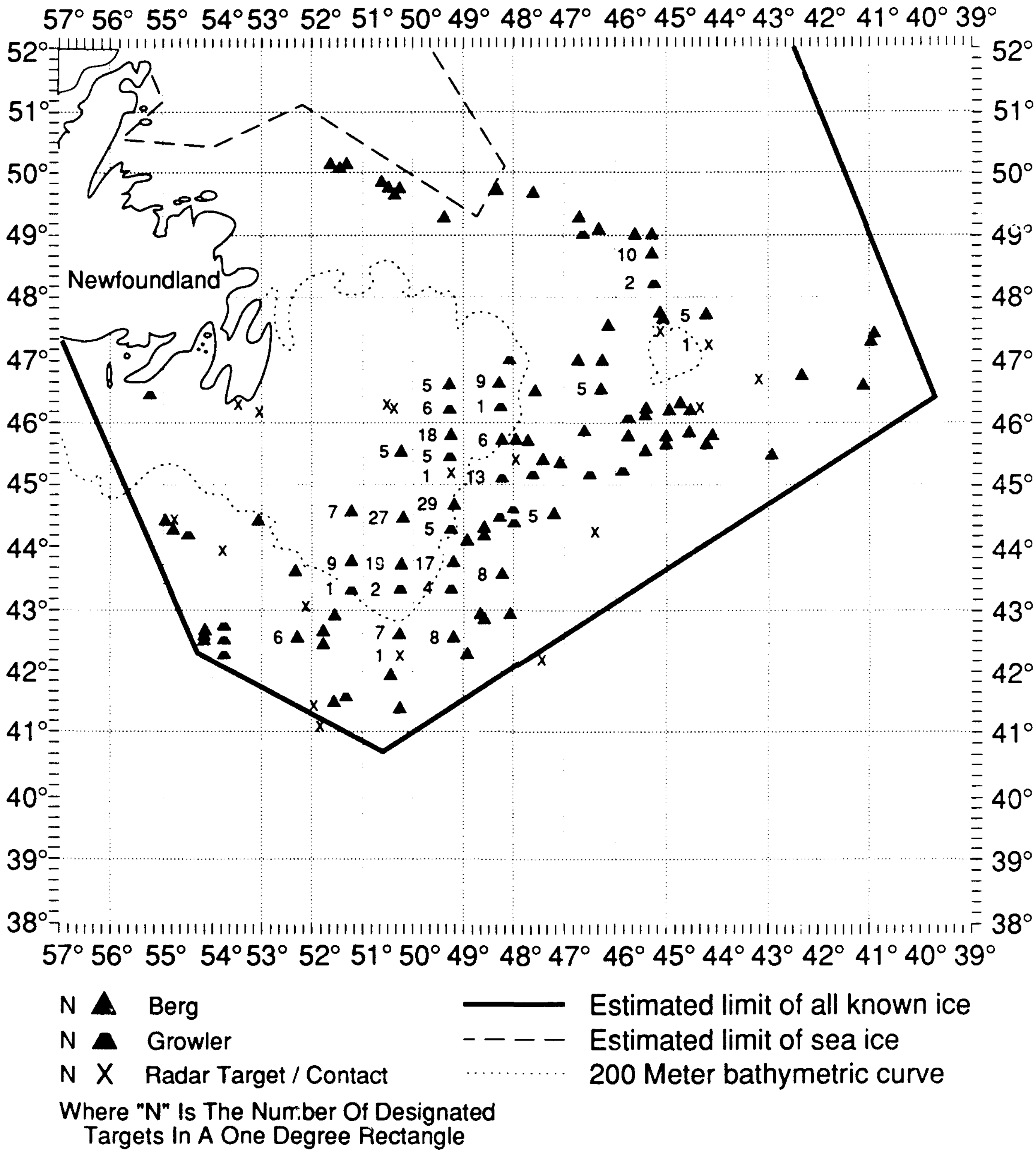


Figure 18. Graphic Depiction Of International Ice Patrol Ice Plot
For 1200 GMT 15APR90 Based On Observed And Forecast Conditions

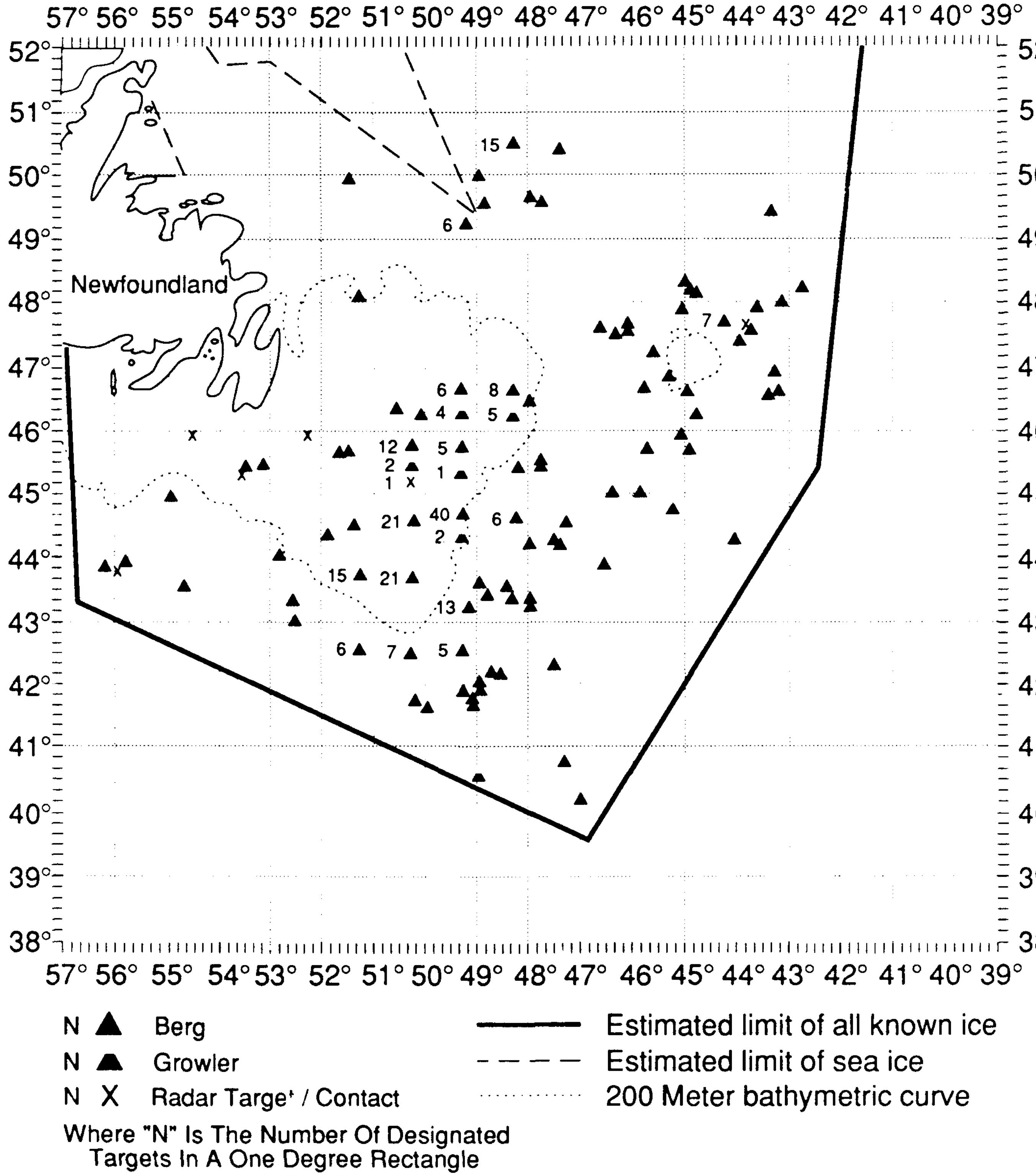
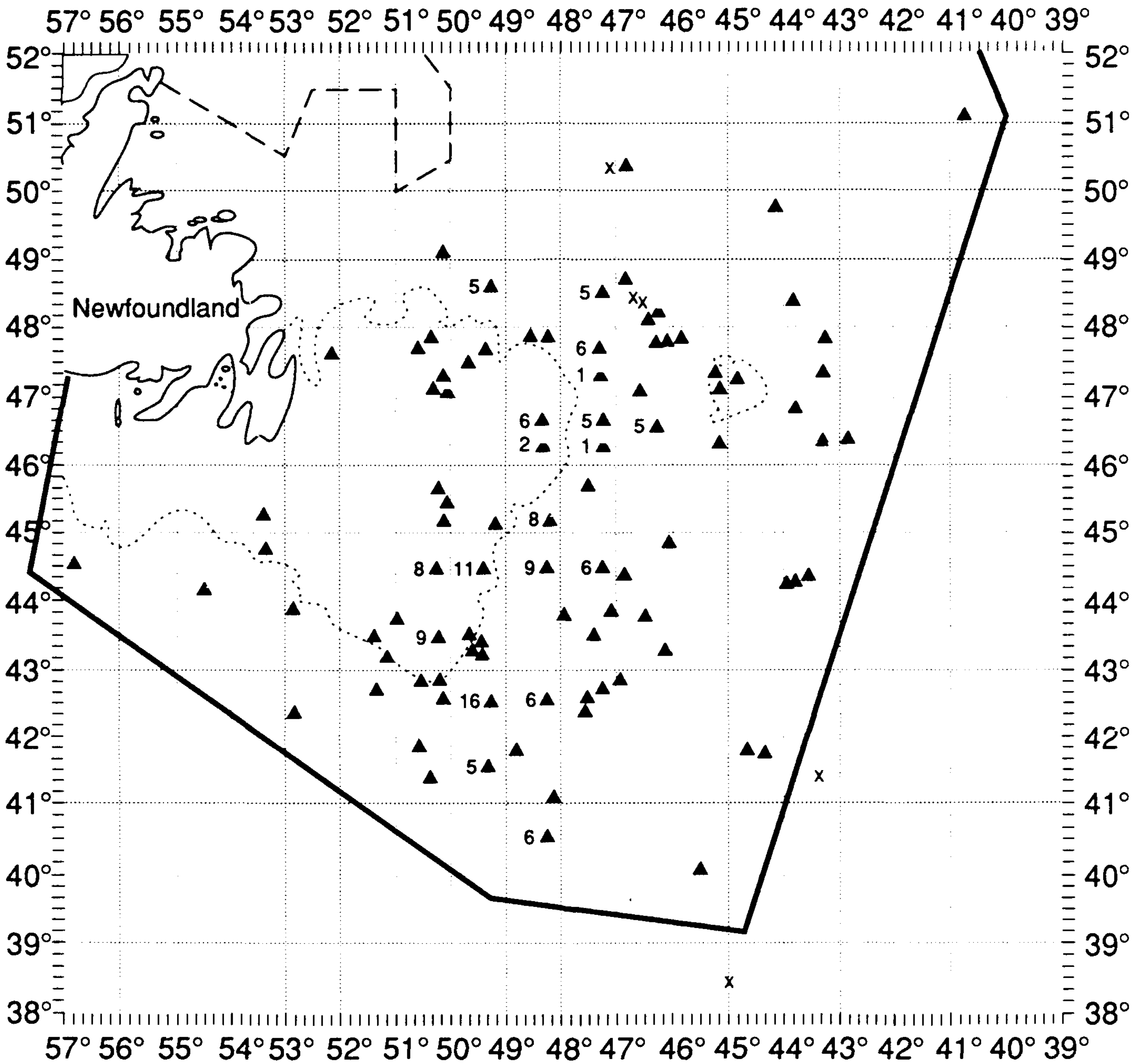


Figure 19. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 30APR90 Based On Observed And Forecast Conditions



N ▲ Berg

N ▲ Growler

N X Radar Target / Contact

Where "N" Is The Number Of Designated Targets In A One Degree Rectangle

——— Estimated limit of all known ice

– – – – Estimated limit of sea ice

.... 200 Meter bathymetric curve

Figure 20. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15MAY90 Based On Observed And Forecast Conditions

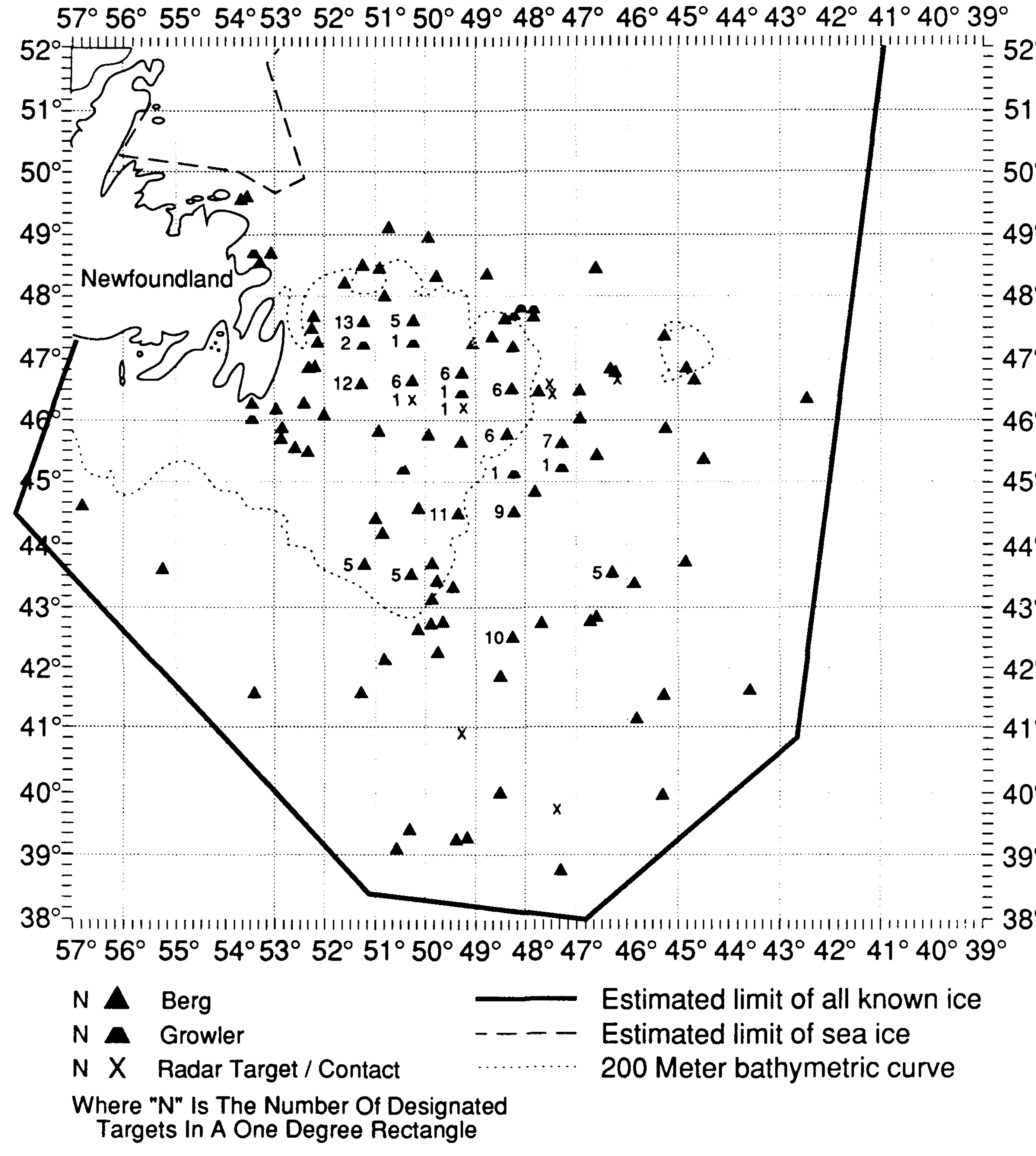


Figure 21. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 30MAY90 Based On Observed And Forecast Conditions

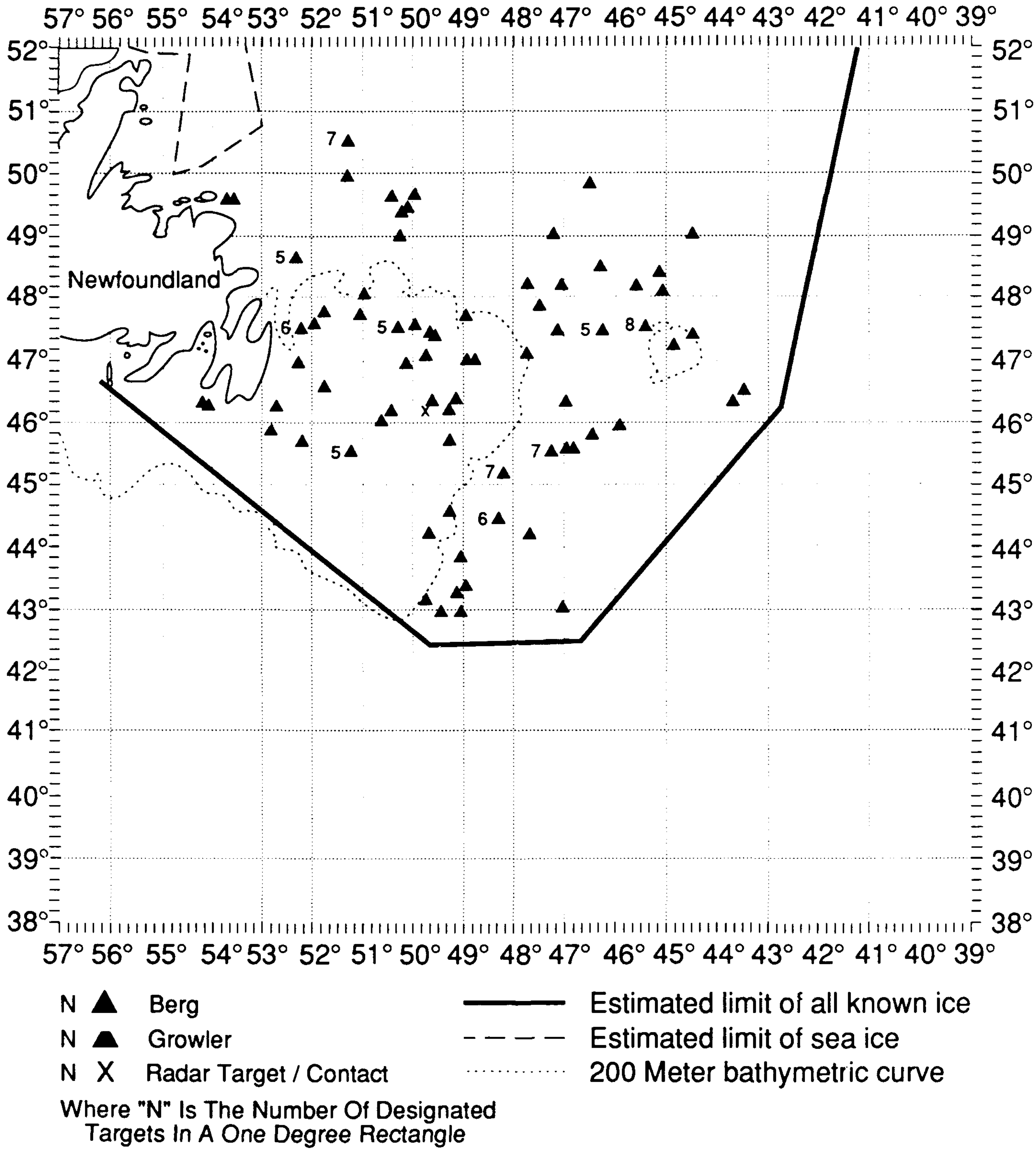


Figure 22. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15JUN90 Based On Observed And Forecast Conditions

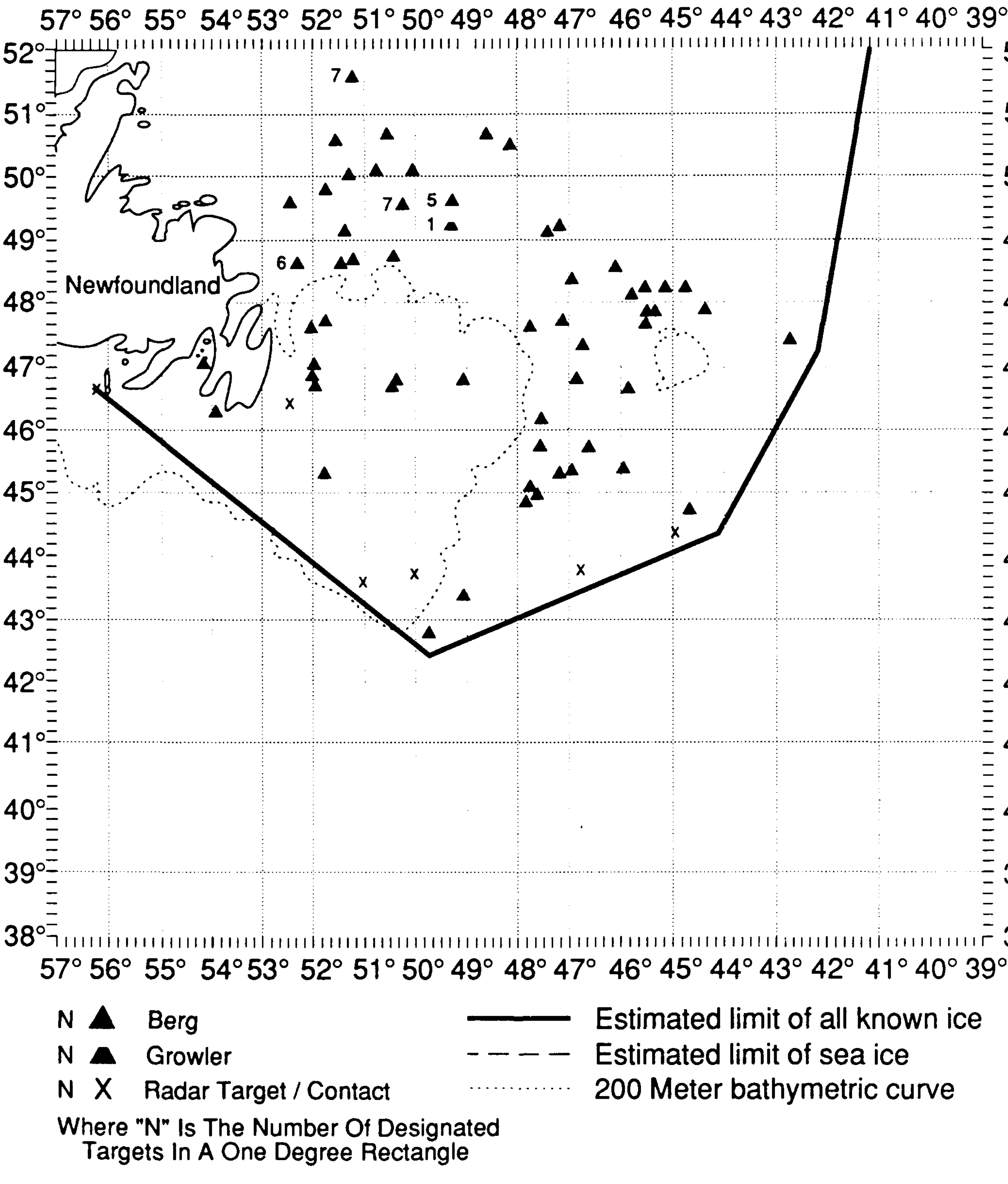
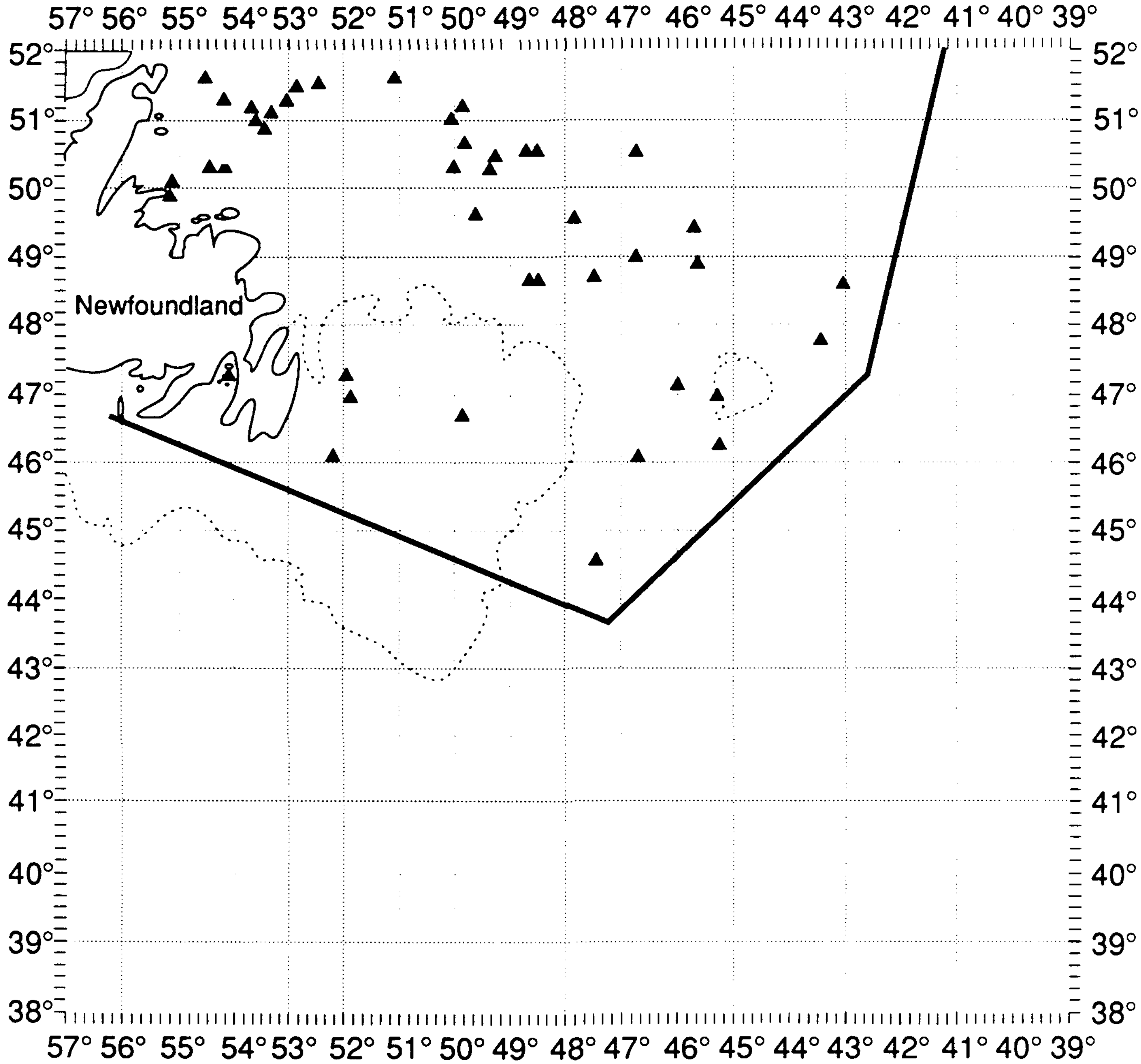


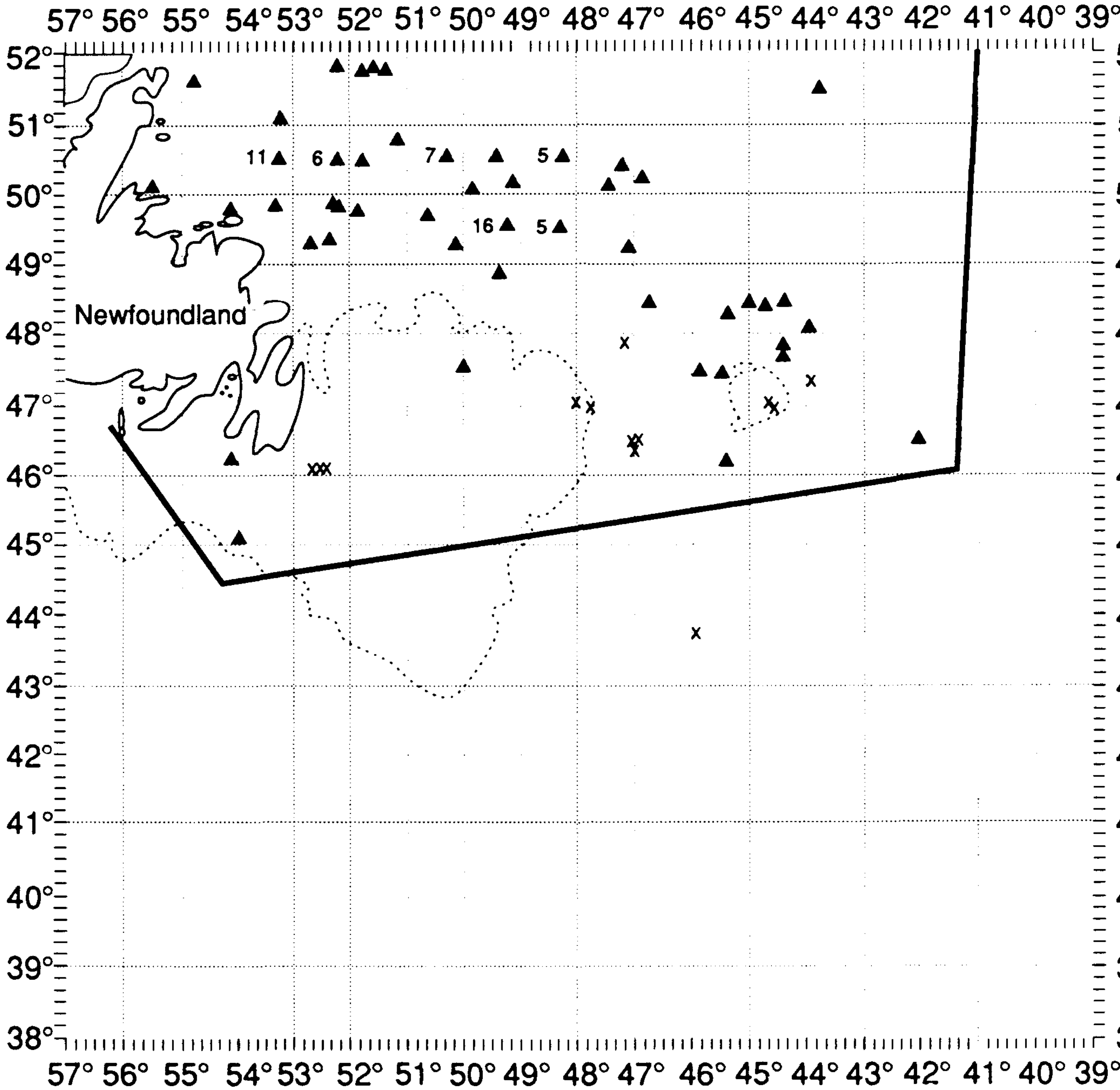
Figure 23. Graphic Depiction Of International Ice Patrol Ice Plot
For 1200 GMT 30JUN90 Based On Observed And Forecast Conditions



N ▲ Berg
N ▲ Growler
N X Radar Target / Contact
Where "N" Is The Number Of Designated Targets In A One Degree Rectangle

——— Estimated limit of all known ice
- - - - Estimated limit of sea ice
········· 200 Meter bathymetric curve

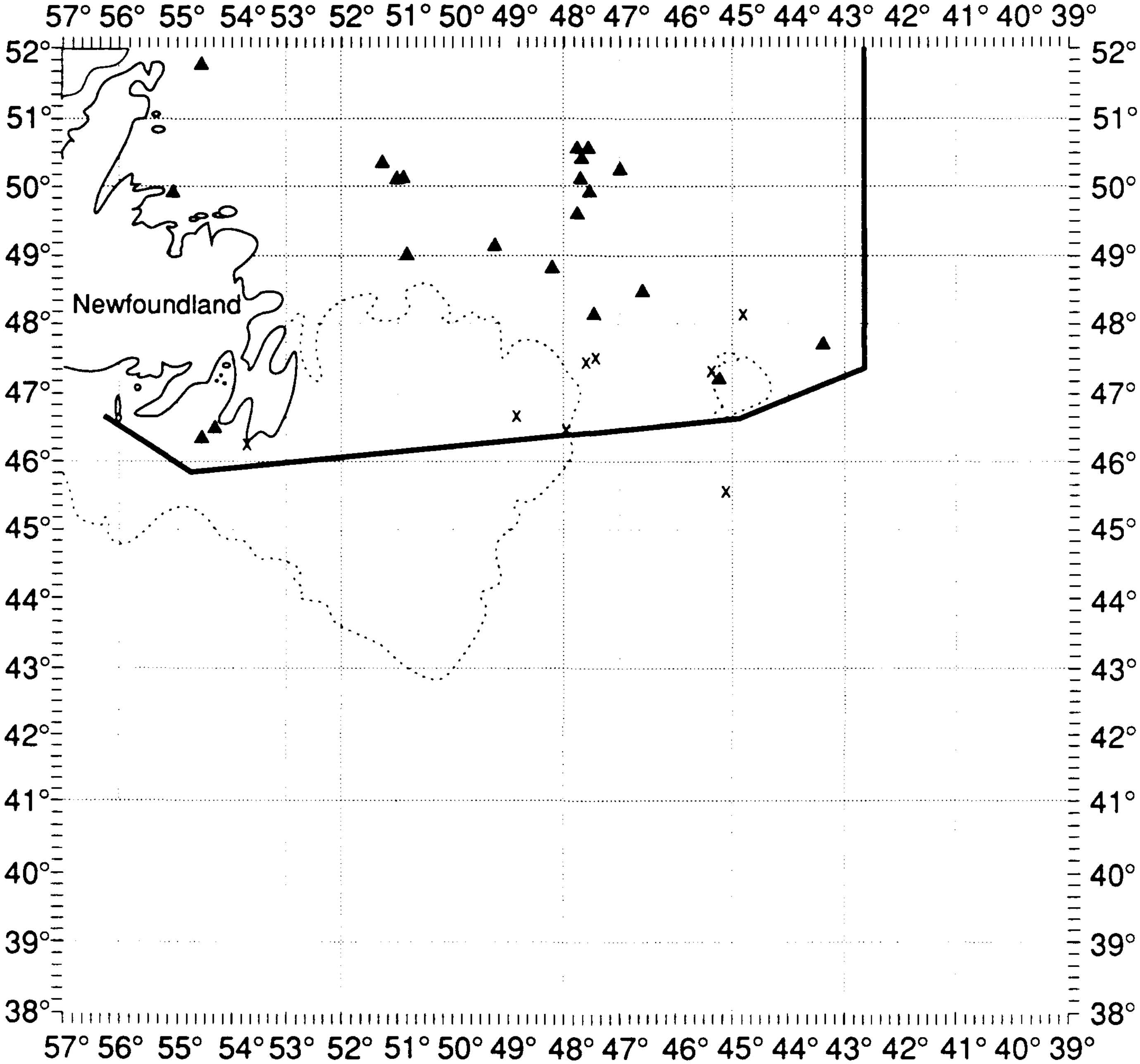
Figure 24. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15JUL90 Based On Observed And Forecast Conditions



N ▲ Berg
N ▲ Growler
N X Radar Target / Contact
Where "N" Is The Number Of Designated Targets In A One Degree Rectangle

Estimated limit of all known ice
Estimated limit of sea ice
200 Meter bathymetric curve

Figure 25. Graphic Depiction Of International Ice Patrol Ice Plot
For 1200 GMT 30JUL90 Based On Observed And Forecast Conditions



N ▲ Berg — Estimated limit of all known ice

N ▲ Growler - - - - Estimated limit of sea ice

N X Radar Target / Contact ········ 200 Meter bathymetric curve

Where "N" Is The Number Of Designated Targets In A One Degree Rectangle

Figure 26. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15AUG90 Based On Observed And Forecast Conditions

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Appendix A
Ship Reports

VESSEL NAME	FLAG	SST	ICE REPORTS
ABEL J	UNKNOWN		1
ABITIBI CLAIBORNE	FED. REP. OF GERMANY		7
ABITIBI CONCORD	FED. REP. OF GERMANY		6
ABITIBI MACADO	FED. REP. OF GERMANY		1
ABITIBI ORINCO	FED. REP. OF GERMANY		5
ACINA	NORWAY		3
ADA GORTHON	BAHAMAS		6
ADAM	SWEDEN		1
ADELE R	BAHAMAS		1
ADMIRALENGRACHT	NETHERLANDS		2
AEGEAN SEA	GREECE		1
AEGIR	BURMA		6
AFRICAN EVERGREEN	LIBERIA	2	2
AIVIK	CANADA		1
AL SAMAD	LIBERIA		2
ALARA	TURKEY	2	2
ALBERTA	GREECE		1
ALDABRA	UNKNOWN		2
ALEKSANDR STAROSTENKO	U. S. S. R.		4
ALFARAHIDI	IRAQ	2	4
ALMARE QUINTA	ITALY	1	1
ALMARE TERZA	ITALY		2
ALSYTA SMITS	NETHERLANDS		1
AMBER	PANAMA		4
AMBROSE SHEA	CANADA		1
AMELIA DESGAGNES	CANADA		3
AMERICA EXPRESS	FED. REP. OF GERMANY	1	2
AMKE	FED. REP. OF GERMANY		1
AMSTELWAL	NETHERLANDS		1
ANANGEL CHAMPION	GREECE		2
ANANGEL PROSPERITY	GREECE		1
ANDREW H	CYPRUS	5	5
ANN HARVEY	CANADA		3
ANTINEA	BAHAMAS		1
APJ ANAND	INDIA	11	1

SST = SEA SURFACE TEMPERATURE

VESSEL NAME	FLAG	SST	ICE REPORTS
APPLEBY	UNITED KINGDOM		1
APTMARINER	LIBERIA		2
AQUARIUS	ITALY		2
ARCADIA	UNKNOWN	2	
ARCTIC	CANADA		2
ARGUS	LIBERIA		4
ARIADNE	SWEDEN		2
ARIS	PANAMA		1
ASL CYGNUS	BAHAMAS		2
ASTERIKS	LIBERIA	1	1
ATLANTIC CARTIER	FRANCE		7
ATLANTIC COMPASS	SWEDEN		1
ATLANTIC CONVEYOR	UNITED KINGDOM		3
ATLANTIC FREIGHTER	BAHAMAS		1
ATLANTIC LINK	NORWAY		3
ATLANTIC MARGARET	CANADA		3
ATLANTIC NORMA	CANADA		1
ATLANTIC OLGA	CANADA		2
ATLANTIC OPTIMIST	CANADA		1
ATLANTIC PEGGY	CANADA		1
ATLANTIC PROSPECT	CANADA		1
ATLANTIC RUTHANN	CANADA		1
ATLANTICO	ITALY		1
BACCALIEU CHALLENGER	UNKNOWN		1
BADAK	LIBERIA		1
BAFFIN	CANADA		2
BALSA	UNKNOWN		1
BALSA 33	PHILLIPINES		2
BALSA 39	PHILLIPINES	1	1
BALTIC SUN	NETHERLANDS		1
BARONIA	PANAMA	4	4
BARRA HEAD	IRELAND		1
BATAAFGRACHT	NETHERLANDS		1
BCM ATLANTIC	CANADA		1
BERGE ODEL	NORWAY		1

VESSEL NAME	FLAG	SST	ICE REPORTS
BERGE PRINCE	NORWAY		1
BERGEN BAY	NORWAY		1
BERING UNIVERSAL	BAHAMAS		1
BIBI	UNITED KINGDOM		1
BLACK SEA	NETHERLANDS		2
BOBBY ESTHER	UNKNOWN		1
BOHINJ	YUGOSLAVIA		2
BORIS	LIBERIA		1
BOW FOREST	NORWAY		7
BOW LADY	NORWAY		1
BRAZILIAN SKY	LIBERIA		1
BREMON SKY	SWEDEN		6
BRIGHT EXPLORER	UNKNOWN		1
BRUSSEL	BELGIUM		3
BURDUR	TURKEY		1
C. S. IRIS	UNITED KINGDOM		1
CABOT	CANADA		8
CANADA MARQUIS	CANADA		1
CANADIAN EXPLORER	UNITED KINGDOM	1	11
CANMAR AMBASSADOR	UNITED KINGDOM		7
CANMAR EUROPE	BELGIUM	3	13
CANMAR SWIFT	SINGAPORE		13
CANMAR VENTURE	UNITED KINGDOM	1	3
CAPE FOX	CANADA		1
CAPE ROGER	CANADA		3
CAPE ROSEWAY	CANADA		1
CARDONA	SPAIN	2	2
CARIBBEAN EXPRESS I	PHILLIPINES		1
CARMEN	SWEDEN		3
CAST BEAVER	YUGOSLAVIA	29	30
CAST CARIBOU	YUGOSLAVIA		3
CAST HUSKY	BAHAMAS		2
CAST MUSKOX	BAHAMAS		4
CAST OTTER	BAHAMAS		10
CAST POLARBEAR	LIBERIA		5

VESSEL NAME	FLAG	SST	ICE REPORTS
CECILIA DESGAGNES	CANADA		3
CHEMBULK CLIPPER	LIBERIA		1
CHERRY VALLEY	UNITED STATES		1
CHITRAL	PAKISTAN	4	
CHRISTINA W	DENMARK		1
CHUSOVOY	U. S. S. R.		1
CLARE	BAHAMAS	4	
CLIPPER ATLANTIC	CYPRUS		1
CLIPPER CRUSADER	PANAMA		6
CONCENSUS MOON	NORWAY		4
CONCERT EXPRESS	SWEDEN		1
CONCORD	FED. REP. OF GERMANY		1
CONFIDENCE	BAHAMAS		1
CONTSHIP	FED. REP. OF GERMANY		3
CORAL WIND	BAHAMAS		1
CORNER BROOK	LIBERIA		4
CRISTOFORO COLOMBO	ITALY	4	7
CUENCA	BAHAMAS		1
CZANTORIA	LIBERIA	3	4
DAN D 2	CANADA		1
DAWSON	CANADA		3
DELOS REEFER	GREECE		1
DENEB	ITALY		1
DEPPE AMERICA	PHILLIPINES		2
DES GROSEILLIERS	CANADA		8
DMITRIV MEDVEDYEV	U. S. S. R.		1
DONA SOPHIA	GREECE	14	
DOOYANG ELITE	SOUTH KOREA		1
DOOYANG FRONTIER	SOUTH KOREA		1
DORA OLDENDORFF	SINGAPORE	18	18
DORADO	ANTIGUA - BARBUBA		3
DRAVA	YUGOSLAVIA		2
DUBROVNIK	YUGOSLAVIA		3
DUSSELDORF EXPRESS	FED. REP. OF GERMANY	1	2
EAGLE ARROW	BAHAMAS		1

VESSEL NAME	FLAG	SST	ICE REPORTS
ECAREG QUEST	CANADA		1
EDUARD CLAUDIUS	GERMAN DEMOCRATIC REPUBLIC		1
EFFY N	CYPRUS		1
ELBE ORE	LIBERIA		1
ELIKON	BAHAMAS	1	1
ELISABETH	CYPRUS	6	9
ELSAM JYLLAND	DENMARK	6	7
ENERCHEM ASPHALT	CANADA		4
ENERCHEM TRAVAILLEUR	CANADA		1
ENLIVENER	PANAMA		1
ENSOR	BELGIUM		4
ERROL M	BAHAMAS		1
ESSO KAOSHIUNG	BAHAMAS		1
EUROPA	LIBERIA		1
EUROPEAN SENATOR	FED. REP. OF GERMANY		1
EUROS	CYPRUS		1
EXPLORER	GREECE	2	2
FAIRNES	CANADA		4
FALCON	NORWAY		8
FALKLANDS DESIRE	UNKNOWN		1
FALKNES	PHILLIPINES	1	1
FAUST	UNITED STATES	1	4
FEDERAL CALUMET	LIBERIA		2
FEDERAL DANUBE	CYPRUS	1	2
FEDERAL INGER	NORWAY		1
FEDERAL MAAS	CYPRUS		7
FEDERAL OTTAWA	BELGIUM		5
FEDERAL POLARIS	JAPAN		1
FEDERAL ST LAURENT	LIBERIA	4	4
FEDERAL THAMES	CYPRUS		3
FERNCRAIG	NORWAY		1
FETISH	DENMARK		2
FILOMENA LEMBO	ITALY		1
FINA AMERICA	BELGIUM	4	5
FINNARCTIC	BAHAMAS		1

VESSEL NAME	FLAG	SST	ICE REPORTS
FINNFIGHTER	FINLAND		12
FJORD LAND	PANAMA		1
FLYING DART	CANADA		4
FORUM PRINCE	CYPRUS	2	
FREENES	LIBERIA		10
FURUNES	PHILLIPINES		1
GLOBAL DREAM	CYPRUS		1
GOLDEN RIO	LIBERIA		2
GRAND COUNT	CANADA		2
GREENLAND SAGA	DENMARK		3
GROSSWATER BAY	CANADA		1
HANCOCK TRADER	CANADA		1
HANS OSCAR	NORWAY	1	1
HAPPY TINE	NORWAY		1
HARP	CANADA	1	7
HASKERLAND	NETHERLANDS		3
HAVKATT	NORWAY		1
HAVTROLL	NORWAY		1
HENRY LARSEN	CANADA		1
HERCEGOVINA	YUGOSLAVIA	1	2
HERUVIM	PANAMA		1
HMCS GATINEAU	UNKNOWN	1	1
HOEGH FOAM	BAHAMAS		1
HOEGH FOUNTAIN	BAHAMAS		1
HOFSJOKULL	ICELAND		1
HONGKONG SENATOR	FED. REP. OF GERMANY		1
HORIZON	LIBERIA		2
HUBERT GAUCHER	CANADA		3
HUDSON	CANADA		18
HUDSONGRACHT	NETHERLANDS		1
HUMBER ARM	LIBERIA		1
ICE PEARL	DENMARK		1
IGNACY DASZYNSKI	POLAND		1
IJMUIDEN MARU	PANAMA		2
IKOMA	PANAMA		1

VESSEL NAME	FLAG	SST	ICE REPORTS
IMPERIAL ACADIA	CANADA		2
IMPERIAL BEDFORD	CANADA		6
INDEPENDENT ENDEAVOR	FED. REP. OF GERMANY		1
INDIRA MAHAL	NEW HEBRIDE		1
INDONESIA VICTORY	PHILLIPINES		1
INN	AUSTRALIA		4
IONIAN EXPRESS	GREECE		1
IRON DUKE	CANADA		1
IRONBRIDGE	HONG KONG		4
IRVING ARCTIC	CANADA		6
IRVING ELM	CANADA		1
IRVING ESKIMO	CANADA		1
IRVING NORDIC	CANADA		1
IRVING OURS POLAIRE	CANADA		1
ISLAND GEM	GREECE	13	15
IVER FALCON	NORWAY		2
J. A. Z. DESGAGNES	CANADA		1
JAHRE TARGET	LIBERIA		1
JALVALLABH	INDIA		2
JENNIE W	UNITED STATES		1
JINYU MARU	JAPAN	1	1
JO GRAN	NORWAY		1
JOANN M	BAHAMAS		2
JOH GORTHON	SWEDEN		1
JOHAN PETERSEN	DENMARK		2
JOHANNA K	PANAMA	2	1
JOHN C HELMSING	CYPRUS		1
JOHN VENTURE	CANADA		2
JORITA	NORWAY	5	4
JUGONAVIGATOR	YUGOSLAVIA		2
JULIA	SINGAPORE		1
KALLIO	CYPRUS		1
KAPITAN KUDLAY	U. S. S. R.		1
KAPITAN REUTOV	U. S. S. R.		1
KAPITAN STANKOV	U. S. S. R.		1

VESSEL NAME	FLAG	SST	ICE REPORTS
KARAYEL 1	TURKEY		3
KATORI	PANAMA	1	1
KAVO YERAKAS	GREECE		1
KEIKO MARU	JAPAN	1	
KHUDOZHNIK PROROKOV	U. S. S. R.		3
KHUDOZHNIK REPIN	U. S. S. R.		2
KIELGRACHT	NETHERLANDS		1
KINGUK	CANADA		2
KNOCK DAVIE	PANAMA	1	1
KOELN ATLANTIC	FED. REP. OF GERMANY		3
KONKAR INTREPID	GREECE		1
LA RICHARDAIS	FRANCE		3
LACKENBY	BAHAMAS		2
LAPPONIA	FINLAND		3
LARINA	LIBERIA		1
LAS GUASIMAS	CUBA		1
LASA	SPAIN		1
LATOUCHE TREVILLE	FRANCE		2
LE BRAVE	CANADA		3
LE CHENE NO. 1	CANADA		1
LEDA MAERSK	DENMARK		1
LELIEGRACHT	NETHERLANDS		3
LEONARD J. COWLEY	CANADA		3
LEOPARD	U. S. S. R.		1
LIBRANAVE II	BRAZIL		6
LOCUST	LIBERIA	1	5
LOK PREM	INDIA		1
LONGEVITY	PHILLIPINES		1
LORETTA V	CYPRUS		1
LT ARGOSY	INDIA	1	1
LT ODYSSEY	INDIA	1	1
LUX CHALLENGER	SPAIN		1
LYNCH	UNITED STATES	38	
MAERSK ZARAGOZA	PANAMA	1	1
MALINSKA	YUGOSLAVIA		1

VESSEL NAME	FLAG	SST	ICE REPORTS
MALOJA II	CYPRUS	19	26
MANTA	FED. REP. OF GERMANY		1
MAREN MAERSK	DENMARK		2
MARGIT GORTHON	BAHAMAS		2
MARIA GL	GREECE	2	2
MARIA GORTHON	SWEDEN		2
MARITA	PHILLIPINES		4
MARSHAL ZHUKOV	U. S. S. R.		1
MARY W	DENMARK	1	8
MAYA NO. 3	PHILLIPINES		1
MAYFAIR	LIBERIA		1
MCKINNEY MAERSK	NORWAY		1
MEERKATZE	FED. REP. OF GERMANY		1
MEGA	BAHAMAS		2
MEGA DALE	NORWAY	1	
MEGA HILL	NORWAY		1
MERRY DOLPHIN	HONG KONG		1
MERSEY VENTURE	CANADA		2
MICHAEL MARINER	CANADA		2
MIKULA	CANADA		1
MISS ALIKI	CYPRUS		1
MITO	LIBERIA		1
MOSEL ORE	LIBERIA		7
MOUTSAINA	LIBERIA		1
MSC CHIARA	ITALY		1
MUSSON	U. S. S. R.		8
NADEZHDA OBUKHOVA	U. S. S. R.		23
NAJA ITTUK	DENMARK		3
NATAARNAQ	DENMARK		1
NAUTILUS	CYPRUS	5	4
NEDLLOYD HUDSON	UNITED STATES		1
NEFTEQORSK	U. S. S. R.		1
NEW LAPIS	LIBERIA	2	2
NILAM	LIBERIA		2
NIMROD	GREECE		4

VESSEL NAME	FLAG	SST	ICE REPORTS
NISSAN BLUEBIRD	LIBERIA	1	
NORDHEIM	SINGAPORE	1	
NORDHOLM	SINGAPORE	3	2
NORDIC	LIBERIA		2
NORMAN MCLEOD ROGERS	CANADA		1
NORMAN SIRINA	NORWAY	2	2
NORTH DUCHESS	GREECE		1
NORTHERN PRINCESS	CANADA		2
NOTOS	CYPRUS		13
NOVA GORICA	YUGOSLAVIA		2
NOVI BEOGRAD	YUGOSLAVIA		2
NUNGU ITTUK	DENMARK		2
NURNBERG ATLANTIC	FED. REP. OF GERMANY		5
OBERON	JAPAN		1
OBUKHOVSKAYA OBORONA	U. S. S. R.		3
ODET	FRANCE		6
OHYO MARU	JAPAN		1
OLYMPIC GLOW	LIBERIA		1
OLYMPIC MIRACLE	GREECE		1
OMISALJ	YUGOSLAVIA		3
OMNIUM PRIDE	CYPRUS		1
OOCL CHALLENGE	UNITED KINGDOM		12
OPSTERLAND	NETHERLANDS		2
ORIENT STAR	LIBERIA	2	
ORIENT SUN	LIBERIA		3
ORIENTAL PATRIOT	CHINA		1
ORJEN	YUGOSLAVIA		1
PACIFIC BREEZE	JAPAN		1
PACIFICO	BAHAMAS		5
PAMIUT	DENMARK		1
PATMOS	GREECE	7	7
PELANDER	LIBERIA	1	2
PERSEVERANCE	SINGAPORE		1
PETIMATA OT RMS	BULGARIA		1
PETROBULK LION	BELGIUM	1	1

VESSEL NAME	FLAG	SST	ICE REPORTS
PETROBULK RAINBOW	LIBERIA	1	1
PHOLAS	UNITED KINGDOM		1
PIONER KOLY	U. S. S. R.		1
PIVA	YUGOSLAVIA		1
POKKINEN	BAHAMAS		4
POLAR NANOQ	GREENLAND		4
POLAR SEA	UNITED STATES	18	16
PONTOKRATIS	GREECE		1
PONTOPOROS	GREECE		3
POSEIDON BREEZE	SINGAPORE	2	2
PROTEKTOR	SINGAPORE		2
PUHOS	BAHAMAS	4	4
QUEEN ELIZABETH II	UNITED KINGDOM		1
RADNIK	PANAMA		1
RAFAELA S	PANAMA		3
RAVENSCRAIG	BAHAMAS		5
RAVNAAS	NORWAY	3	3
RAVNI KOTARI	YUGOSLAVIA		1
RED ROSE	CYPRUS	4	4
REGINA OLDENDORFF	UNITED KINGDOM	3	5
RIALTO	LIBERIA	2	3
RIO MOA	CUBA		3
RIO VISTA	UNITED KINGDOM		1
RISNES	UNITED STATES		1
ROBERTA D'ALESIO	ITALY		1
ROSELLEN	CYPRUS		1
RUBI	SPAIN		1
RUDJER BOSKOVIC	YUGOSLAVIA	1	1
RUDOLF LEONHARD	GERMAN DEMOCRATIC REPUBLIC		5
S KIROV	U. S. S. R.		7
SAAR ORE	LIBERIA		5
SAC MALAGA	SPAIN		1
SAINT PIERRE	FRANCE		1
SAN LORENZO	UNITED KINGDOM		8
SAN SALVADOR	SPAIN		1

VESSEL NAME	FLAG	SST	ICE REPORTS
SANKO PEARL	LIBERIA		1
SAPPHIRE	PHILLIPINES		4
SASKATCHEWAN PIONEER	CANADA		4
SCANDINAVIAN SUN	BAHAMAS		1
SCANTRO	NORWAY	1	
SCARAB	DENMARK		3
SEA HORSE	BURMA		1
SEA-LAND QUALITY	UNITED STATES		3
SEACROSS	MALTA		1
SEALUCK III	CYPRESS		1
SELIGER	U. S. S. R.		1
SELKIRK SETTLER	UNITED KINGDOM		3
SELNES	CYPRUS		8
SEVASTOPOLSKAYA BUKHTA	U. S. S. R.		2
SEVEN G'S	UNITED STATES		1
SHINKAI MARU	JAPAN		3
SIC KIM	UNITED STATES		1
SILVER FAITH	BAHAMAS	2	
SIR HUMPHREY GILBERT	CANADA		3
SISALA	NORWAY		1
SIVONA	SWEDEN		1
SKARHEIM	NORWAY		1
SKOGAFOSS	ANTIGUA - BARBUDA		4
SKULPTOR MATVEYEV	U. S. S. R.		1
SLOLT SPAN	LIBERIA		3
SNOEKGRACHT	NETHERLANDS		4
SOLIN	YUGOSLAVIA		3
SOLITA	BAHAMAS	1	
SOREN TOUBRO	INDIA		2
SPAR	UNITED STATES		3
SPLIT	YUGOSLAVIA		2
STAR FINLANDIA	DENMARK		1
STAR MAGNATE	UNITED KINGDOM	1	1
STAR TRONDANGER	NORWAY		1
STATE OF ANDHRA PRADESH	INDIA		1

VESSEL NAME	FLAG	SST	ICE REPORTS
STEFANOS	GREECE		2
STENHOLM	UNKNOWN		1
STOLT ACCORD	LIBERIA		4
STOLT ASPIRATION	LIBERIA		1
STOLT CROWN	LIBERIA	4	1
STOLT FALDA	NORWAY		2
STOLT PRIDE	LIBERIA		2
STOLT SAKRA	LIBERIA		1
STOLT SYDNESS	LIBERIA	1	3
STUTTGART EXPRESS	FED. REP. OF GERMANY	2	2
SUNGALE	ANTIGUA - BARBUDA		1
SVANGEN	PANAMA	4	3
TADEUSZ KOSCIUSZKO	POLAND		2
TAKACHINO MARU	JAPAN		4
TAMARA	MALTA		3
TAMPA BAY	UNITED STATES		1
TAMPERE	NORWAY		4
TAVERNOR	CANADA		1
TAVI	FINLAND		1
TAWAKI	UNITED STATES		5
TEXACO BERGEN	NORWAY		1
THALASSINI AVRA	GREECE		2
THANASSIS	MALTA		1
THULELAND	SWEDEN		1
TNT EXPRESS	UNITED KINGDOM		2
TOLTEK	FED. REP. OF GERMANY		6
TRAVE ORE	CHINA		1
TREBIZOND	LIBERIA		1
TRIUMPH SEA	CANADA		3
TYR	ICELAND		2
UAL MONTREAL	GREENLAND		7
UMBRINA	U. S. S. R.		1
UNITED VENTURE	SINGAPORE		1
UNITY 1	PANAMA		3
VALDIVIA	UNITED KINGDOM	1	1

VESSEL NAME	FLAG	SST	ICE REPORTS
VALLATHOL	INDIA		1
VARJAKKA	BAHAMAS		1
VERMA	CYPRESS	1	1
VESALIUS	BELGIUM		1
VIBRO ATLANTIC	NORWAY		1
VITASKY	PANAMA		1
VITYAZ	U. S. S. R.		6
VOLNA	U. S. S. R.		3
VRAHOS	HONDURAS		1
VSEVOLOD	U. S. S. R.		1
WATER FINA	CYPRESS		1
WATERGIDS	NETHERLANDS		11
WATERKONING	NETHERLANDS		4
WATERSTOKER	NETHERLANDS	1	1
WESER GUIDE	FED. REP. OF GERMANY		3
WILFRED TEMPLEMAN	CANADA		10
WILLIAM	SINGAPORE		22
WIND SOVEREIGN	NORWAY		2
WIND SPIRIT	NORWAY		1
WLADYSLAW SIKORSKI	POLAND	1	3
WORLD ADVENTURE	LIBERIA		1
YIN KIM	PANAMA		2
YOUNG SKIPPER	LIBERIA		1
YUNUS II	TURKEY		2
ZAMA	LIBERIA		1
ZAMBES I	CANADA		2
ZAMORA	CANADA		1
ZANDBERG	CANADA		2
ZANDVOORT	CANADA		1
ZAWRAT	POLAND	6	5
ZEILA	CANADA		3
ZIEMIA LUBELSKA	POLAND		1
ZIEMIA OLSZTYNSKA	POLAND		1
ZIEMIA SUWALSKA	POLAND	2	3
ZIEMIA ZAMOJSKA	POLAND	10	20

VESSEL NAME	FLAG	SST	ICE REPORTS
ZIM IBERIA	ISRAEL		1
ZIM KEELING	ISRAEL		2
ZIM PUSAN	GREECE	6	
ZIM SAVANNAH	ISRAEL		2
ZURITA	CANADA		1

Appendix B

International Ice Patrol's 1990 Drifting Buoy Program

Alfred T. Ezman

INTRODUCTION

The 1990 iceberg season was the fifteenth consecutive year that the International Ice Patrol (IIP) has used satellite-tracked buoys to measure currents in its operations area in the western North Atlantic Ocean. Buoy trajectories are used to provide near real time current data to the Ice Patrol iceberg drift model. Currents derived from the buoy trajectories are used to temporarily modify the mean currents in the region through which the buoys drift. Shortly after a buoy departs the region, the current is reverted to its mean value (Summy and Anderson, 1983).

During the 1990 Ice Patrol season the Ice Patrol deployed ten buoys (Table B-1). Five of these were in the standard configuration de-

Table B-1. Summary of 1990 Deployments

ARGOS ID	BUOY TYPE	FINAL DEPLOYMENT DATE	DEPLOYMENT POSITION	REMARKS
4530	TOD	10 APR (100)	4700.0°N, 4720.2°W	Last position plotted 19 NOV(323) Departed OPAREA 17 NOV(321,
9877	TOD	10 MAY (130)	4349.0°N, 4913.0°W	Failed in OPAREA 23 JUL(204) Stopped transmitting 24 JUL(205)
4561	TOD	08 JUN (159)	4700.0°N, 4733.0°W	Departed OPAREA 13 AUG(225)
9878	TOD	08 JUN (159)	5700.0°N, 5135.0°W	Departed OPAREA 20 OCT(293)
4542	TOD	22 JUN (173)	4859.7°N, 4949.7°W	Departed OPAREA 14 AUG(226)
11830	HZ MAR	23 JUN (174)	4735.1°N, 5234.8°W	Continued transmitting at same location Failed in OPAREA 30 SEP(273)
11831	HZ MAR	23 JUN (174)	4859.7°N, 4949.7°W	Failed in OPAREA 13 OCT(286)
11832	HZ MAR	23 JUN (174)	4859.8°N, 4949.8°W	Departed OPAREA 16 OCT(289)
9881	CMOD	22 JUN (173)	4902.4°N, 5024.2°W	Failed in OPAREA 11 AUG(223)
9882	CMOD	23 JUN (174)	4735.1°N, 5234.8°W	Departed OPAREA 19 OCT(292)

scribed below; three of the ten buoys deployed were Horizon Marine minibuoys; two were MET Ocean minibuoys (CMOD). The International Ice Patrol deployed the minibuoys to compare the information received from them and their characteristics with that of the larger, more expensive buoys the Ice Patrol has used traditionally. The five minibuoys were used for research purposes only. They were tested to determine their long-term survivability. Information gained from this study will be published by the International Ice Patrol in an appropriate forum at a later date.

The standard configuration for the operational buoys was a 3-m-long spar hull with a 1-m-diameter flotation collar. Each buoy was equipped with a 2-m by 10-m window shade drogue attached to the buoy with a 50-m tether of 1.3-cm (0.5 in) nylon. The center for the drogue was at a nominal depth of 58 m. Each buoy had a temperature sensor (accurate to approximately 1°C) mounted approximately 1 m below the waterline, a drogue tension monitor, and a battery voltage monitor. Two of the buoys deployed during 1990 (9877 and 9878) were equipped with barometric pressure sensors funded by the U. S. Navy.

The data from the buoys are acquired and processed by Service ARGOS. Ice Patrol queries the ARGOS data files and stores the buoy data once daily. Most of the buoy position data fall within the standard accuracy provided by Service ARGOS (approximately 350 m). Operational buoy data were entered into the Global Telecommunications System (GTS) using their assigned World Meteorological Organization (WMO) numbers.

BUOY DEPLOYMENT STRATEGY

Monitoring the currents with drifting buoys in the entire Ice Patrol operations area (40°N to 52°N; 39°W to 57°W) for the entire iceberg season is impractical. A recent study (FENCO 1987) showed that at least 400 buoys would be required to resolve the eddy field in a 250-km by 250-km area, an area less than 5% of IIP's total operational area. The costs associated with deploying and tracking hundreds of buoys far exceeds the entire Ice Patrol budget.

Per our general approach, Ice Patrol's 1990 buoy deployment strategy focused on the current that is the major conduit of icebergs to the North Atlantic shipping lanes, the southward flowing off-shore branch of the Labrador Current. Generally IIP attempts to monitor this current for the entire season by keeping one or two buoys in it at all times.

Buoys are deployed as far north as possible within the OPAREA (north of 50°N) because the southward mean flow of the Labrador Current carries the buoys into the southern areas of interest. Ice Patrol's experience has shown that this approach is reasonable within limitations. Early in the iceberg season (March and April), buoys can not be deployed in areas with significant concentrations of sea ice (<3/10) because wind-driven movement of the sea ice contaminates the drifter data, and sea ice can damage the buoy. In many cases buoys deployed between 50°N to 52°N move eastward north of the Flemish Cap, and therefore do not enter our primary region of interest south of Flemish Pass. It is frequently necessary to

deploy buoys directly in Flemish pass to ensure that the buoys will move to the south because Ice Patrol requires drift data in this area. To accomplish this objective buoys often are deployed at 47°N between 46-30°W and 47-30°W.

AIRCRAFT DEPLOYMENTS

Ice Patrol has deployed satellite-tracked buoys from HC-130 aircraft since 1979. The buoy is strapped into an air-deployment package and launched out the rear door of an HC-130 flying at an altitude of 150 m (500 ft) at 77 m/s (150 kts). The air-deployment package consists of a wooden pallet and a parachute, both of which separate from the buoy after it enters the water. The parachute riser is cut by a cable cutter that is activated by a battery energized when immersed in salt water. The pallet separates when salt tablets dissolve and release straps holding the buoy to the pallet. The buoy floats free, and the drogue falls and unfurls. The Ice Patrol air-deployed 4 of these buoys during the 1990 season. The remaining 6 buoys were ship- deployed.

DATA PROCESSING

The raw position and temperature data are relatively noise free, however, all records are reviewed before processing to ensure quality control. Duplicate positions and positions with time separations of 30 minutes or less are deleted. Positions less than 700 m from adjacent positions are deleted, unless the deletion results in a time separation of four or more hours.

The quality-controlled position data are then fitted to a cubic spline curve to arrive at an evenly spaced record with time intervals of three hours. This process results in a slight reduction in the number of fixes per day (from 10 to 8). The position records are then filtered using a low-pass cosine filter with a cut-off of 1.6×10^{-5} Hz (one cycle per day). This filter removes most tidal and inertial effects. The buoy drift speeds are calculated at three-hour intervals using a two-point backward differencing scheme.

The trajectory plots presented in this report are from the filtered records. Also presented for each buoy is a plot of the time history of the U (eastward is positive) and V (northward is positive) components of velocity from the filtered records. A time history of the raw sea surface temperature data is plotted for each buoy. The dates used in all of the plots are year-days, which are numbered sequentially starting at 1 on 1 January. The year-days are included parenthetically in the text.

BUOY TRAJECTORIES

The following sections discuss each buoy trajectory in chronological order by buoy deployment date. The discussions summarize each buoy's performance and the data it contributed to Ice Patrol operations. The summaries are not intended to be an exhaustive data analysis. Buoy data from the area east of 39°W, the eastern boundary of the Ice Patrol's operations area, are not presented. Data from the IIP buoy program are archived at the IIP office in Groton, Connecticut and the Marine Environmental Data Service (MEDS), Department of Fisheries and Oceans.

BUOY 4530

Buoy 4530 (Figure B-1) was deployed at 1530Z on 10 April (100) at 4700.0°N, 4720.2°W. It remained within the International Ice Patrol operations area for 221 days, passing east of 39°W on 17 November (321). The drogue sensor indicated that the drogue was attached throughout its operations period.

Buoy 4530 drifted through Flemish Pass and then southward in the Labrador Current until day 114. Speeds in the Flemish Pass area ranged from 9 cm/s to 52 cm/s. Temperatures increased from -1.5°C to 0.4°C while the buoy traveled southward in the Labrador Current. Buoy 4530 began a series of cyclonic loops between days 115 and 214. Temperatures in the eddies varied between 0.1°C and 2.2°C. Speeds during this period (days 115 to 214) were 0.5 cm/s to 58 cm/s. Under the influence of the North Atlantic Current, buoy 4530 drifted eastward (days 215 to 225) and then began a series of complex loops until day 303. During this time frame (days 215 to 303) the temperatures ranged from 11°C to 18°C, and buoy drift speed ranged from 5 cm/s to 116 cm/s. Buoy 4530 looped northward and then drifted out of the Ice Patrol operations area on 17 November (day 321). The sea surface temperatures varied from 11°C to 13°C, and buoy speeds ranged from 12 cm/s to 118 cm/s during this last segment.

BUOY 9877

Buoy 9877 (Figure B-2) was deployed at 1826Z on 10 May (130) at 4349.0°N, 4913.0°W. It failed within the Ice Patrol operations area on 23 July (204). The drogue sensor indicated that the drogue was connected throughout its operational period.

Buoy 9877 drifted along the 200-m contour paralleling the Grand Banks at speeds of 7 cm/s to 27 cm/s from day 130 to day 163, with the exception of days 150 to 158, where it completed a small cyclonic gyre. During this period (days 130 to 163) the temperatures increased from .4°C to 5°C. Buoy 9877 traveled south until day 169, east until day 174 and then headed in a general northern direction until it failed on day 204. The temperatures ranged from 5°C to 10°C on its southern leg, 10°C to 16°C on its eastern leg, and remained at 14°C ± 2°C until day 204. The speeds ranged from 20 cm/s to 45 cm/s on its southern and eastern legs, from 9 cm/s to 20 cm/s on days 175 to 192, and 0.4 cm/s to 5 cm/s on days 193 to 204.

BUOY 4561

Buoy 4561 (Figure B-3) was deployed at 1346Z on 8 June (159) at 4700.0°N, 4733.0°W. It remained within the International Ice Patrol operations area for 66 days, departing to the east of 39°W on 13 August (225). The drogue sensor indicated that the drogue was connected throughout its operational period.

Buoy 4561 drifted southward in the Labrador Current along the 1000-m contour at speeds of 20 cm/s to 68 cm/s until day 174. Temperatures gradually increased from 1°C to 7°C from days 159 to 174. The North Atlantic Current drifted buoy 4561 to the east for the next 3 days and then to the northeast from days 177 to 208. On day 209 the buoy began a series of anticyclonic gyres (3 total) while heading toward the

northeast until it departed the operations area on day 225. While heading to the northeast the buoy drifted at a wide range of speeds including 120 cm/s on days 200 and 201. The temperatures gradually increased from 10°C to 16°C during days 174 to 225.

BUOY 9878

Buoy 9878 (Figure B-4) was deployed at 1215Z on 8 June (159) at 5100.0°N, 5135.0°W. It remained within the Ice Patrol operations area for 134 days, passing east of 39°W on 20 October (293). The drogue sensor indicated that the drogue was connected until 2300Z, 6 October (279).

Buoy 9878 drifted southward in the Labrador Current through Flemish Pass until 14 September (257). As the buoy drifted southward, the temperatures and buoy speeds varied from 1°C to 20°C and 2 cm/s to 80 cm/s respectively. During this southward drift (days 232 to 247), the buoy completed a cyclonic gyre. Speeds during this period were 10 cm/s to 45 cm/s, and temperatures were 15°C to 20°C. After day 257, the buoy began to drift to the east under the influence of the North Atlantic Current. During this period (days 257 to 293), the buoy drift was unremarkable. Speeds ranged form 9 cm/s to 100 cm/s with the greatest speeds occuring when the buoy was located directly south of Flemish Cap. The temperatures varied from 19°C to 23°C.

BUOY 4542

Buoy 4542 (FigureB-5) was deployed at 1740Z on 22 June (173) at 4859.9°N, 4949.7°W. It remained within the Ice Patrol operations area for 53 days, departing to the north of 52°N on 14 August (226).

Buoy 4542 drifted eastward parallel to the 200-m contour to the north of Flemish Cap (day 197). The speeds and temperatures along this drift ranged from 12 cm/s to 40 cm/s and 2°C to 7°C respectively. After day 197, buoy 4542 drifted toward the northwest from days 204 to 218. The buoy completed a small cyclonic gyre and then continued to drift to the northwest until it drifted north of 52°N on 14 August (226). As buoy 4542 began drifting toward the northwest, the sea surface temperature jumped from 7°C to 12°C and remained at 12°C until day 207 when it dropped to 9°C and fluctuated ± 2°C until drifting out of the International Ice Patrol operations area. The drifting speeds of buoy 4542 on day 197 gradually rose from 12 cm/s to 57 cm/s on day 201, and then gradually fell to 9 cm/s on day 215, only to climb to 21 cm/s before drifting north of 52°N.

BUOY 11830

Buoy 11830 (Figure B-6) was deployed at 1715Z on 23 June (174) at 4735.1°N, 5234.8°W. It failed within the International Ice Patrol operations area on 30 September (273). Buoy 11830 did not have a temperature sensor.

Buoy 11830 remained in the immediate vicinity of Newfoundland, Canada throughout its deployment. Its drift path was complex but unremarkable. Buoy drift speeds reached a maximum of 28 cm/s, but for the most part the buoy speeds remained in the single digit and low teen range.

BUOY 11831

Buoy 11831 (Figure B-7) was deployed at 1748Z on 23 June (174) at 4859.7°N, 4949.7°W. It failed within the International Ice Patrol operations area on 13 October (286). Buoy 11831 did not have a temperature sensor.

Buoy 11831 drifted eastward along the 200-m contour to the north of Flemish Cap (day 189). During this drift period, buoy speeds ranged from 20 cm/s to 30 cm/s. Buoy 11831 then drifted southeast continuing to parallel the 200-m contour encompassing Flemish Cap. Under the influence of the North Atlantic Current (day 214), the buoy began to drift north until day 226 and then northwest until day 249 at speeds of 9 cm/s to 60 cm/s. Buoy drift became more complex as the buoy drifted generally to the north, completeing two anticyclonic gyres in the process. On day 278, the buoy drifted towards the east until it failed in the International Ice Patrol operations area. Speeds during the period (days 250 to 286) were 10 cm/s to 50 cm/s.

BUOY 11832

Buoy 11832 (Figure B-8) was deployed at 1736Z on 23 June (174) at 4859.8°N, 4949.8°W. It drifted to the east of 39°W out of the International Ice Patrol operations area on 16 October (289). Buoy 11832 did not have a temperature sensor.

Buoy 11832 drifted eastward to the north of Flemish Cap and then southeast around Flemish Cap paralleling the 200-m countour. Speeds during this period (days 174 to 215) ranged from 5 cm/s to 30 cm/s. Buoy 11832 drifted north until day 242 when it began a series of loops ending day 286. On day 289, buoy 11832 drifted out of the International Ice Patrol operations area. Speeds throughout its northern drift were 5 cm/s to 50 cm/s.

BUOY 9881

Buoy 9881 (Figure B-9) was deployed at 1232Z on 22 June (173) at 4902.4°N, 5024.2°W. It failed within the Ice Patrol operations area on 11 August (223).

Buoy 9881 drifted westward along the 200-m contour to the north of Flemish Cap until day 189 and then generally northeastward under the influence of the North Atlantic Current until day 223. Temperatures gradually increased from days 173 to 189 from 2.5°C to 6.4°C, and speeds varied form 20 to 40 cm/s. On day 196, the buoy began drifting in a figure eight pattern and experienced a sudden jump in temperature from 8°C to 12°C. Speeds varied from 9 cm/s to 40 cm/s. On day 211, after the completion of the figure eight pattern, sea surface temperature returned to 8°C and gradually rose to 14°C until day 223. The speeds during this period (days 211 to 223) were 29 cm/s to 75 cm/s.

BUOY 9882

Buoy 9882 (Figure B-10) was deployed at 1202Z on 23 June (174) at 4735.1°N, 5234.8°W. It remained within the Ice Patrol operations area for 118 days, passing east of 39°W on 19 October (292).

Buoy 9882 drifted east relatively slowly (maximum speed 20 cm/s) until day 220. Temperatures

ranged from 2°C to 12°C during this period. Buoy speeds increased form 5 cm/s to 54 cm/s during the next 9 days as the buoy continued to drift toward the east. Buoy 9882 continued to slowly drift eastward over Flemish Cap at speeds ranging from 9 cm/s to 30 cm/s. Temperatures varied from 10°C to 15°C. As buoy 9882 continued to drift toward the east, it completed one cyclonic gyre (days 275 to 287) and then finally departed the International Ice Patrol operations area on day 292. Buoy speeds and sea surface temperatures were 25 cm/s to 60 cm/s and 12°C to 15°C respectively.

SUMMARY AND CONCLUSIONS

The performance of the ten operational buoys deployed during the 1990 season was adequate for IIP use. The average number of days a buoy remained deployed within the IIP area was 104. Buoy 4561 remained within the IIP operations area providing information for 221 days.

Most of the 1990 buoy trajectories followed one of two general flow patterns. Buoys drifting within the 100-m contour passed through Flemish Pass under the influence of the Labrador Current. The North Atlantic Current would then drift the buoy to the northeast. The buoy trajectories of Buoys 4542, 4561, 4530, and 9878 were indicative of this flow pattern. Buoys deployed offshore of the 1000-m contour drifted to the north of Flemish Cap. The trajectories of Buoys 11831, 11832, 9881, and 9882 were indicative of this flow pattern. Buoys 9877 and 11830 remained in the general area in which they were deployed as long as they were transmitting data.

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Summy, A. D. and I. Anderson, 1983. Operational Use of TIROS Oceanographic Drifters by International Ice Patrol (1978-1982). Proceedings of the 1983 Symposium on Buoy Technology. Marine Technology Society, 1825K Street, N.W., Suite 203, Washington, D.C. 20593, pp. 246-250.

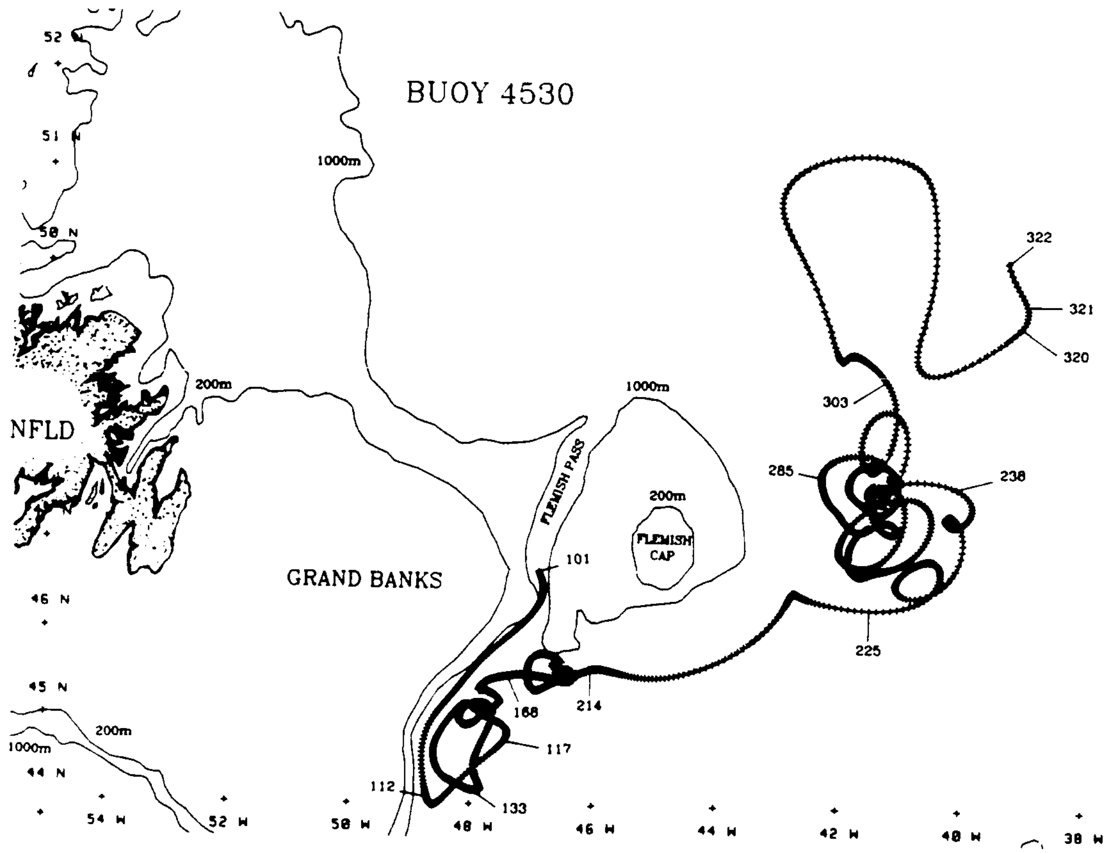

Figure B-1a. Trajectory for 4530

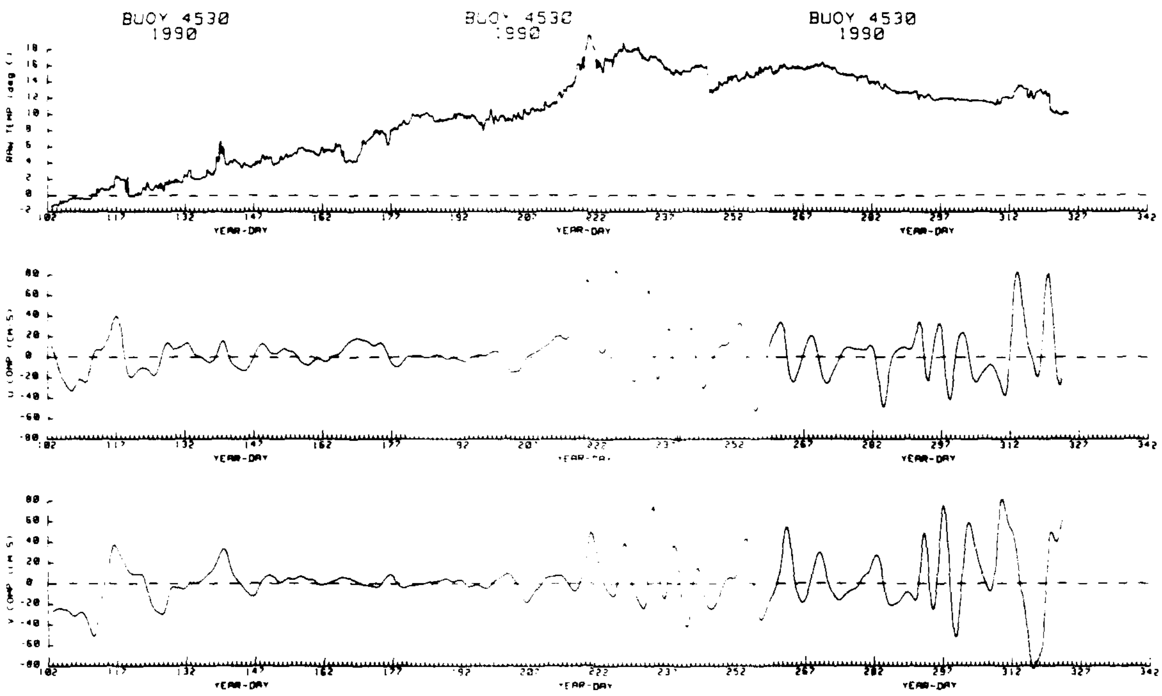

Figure B-1b. Time history of sea surface temperature, U, and V velocity components (filtered) for 4530.

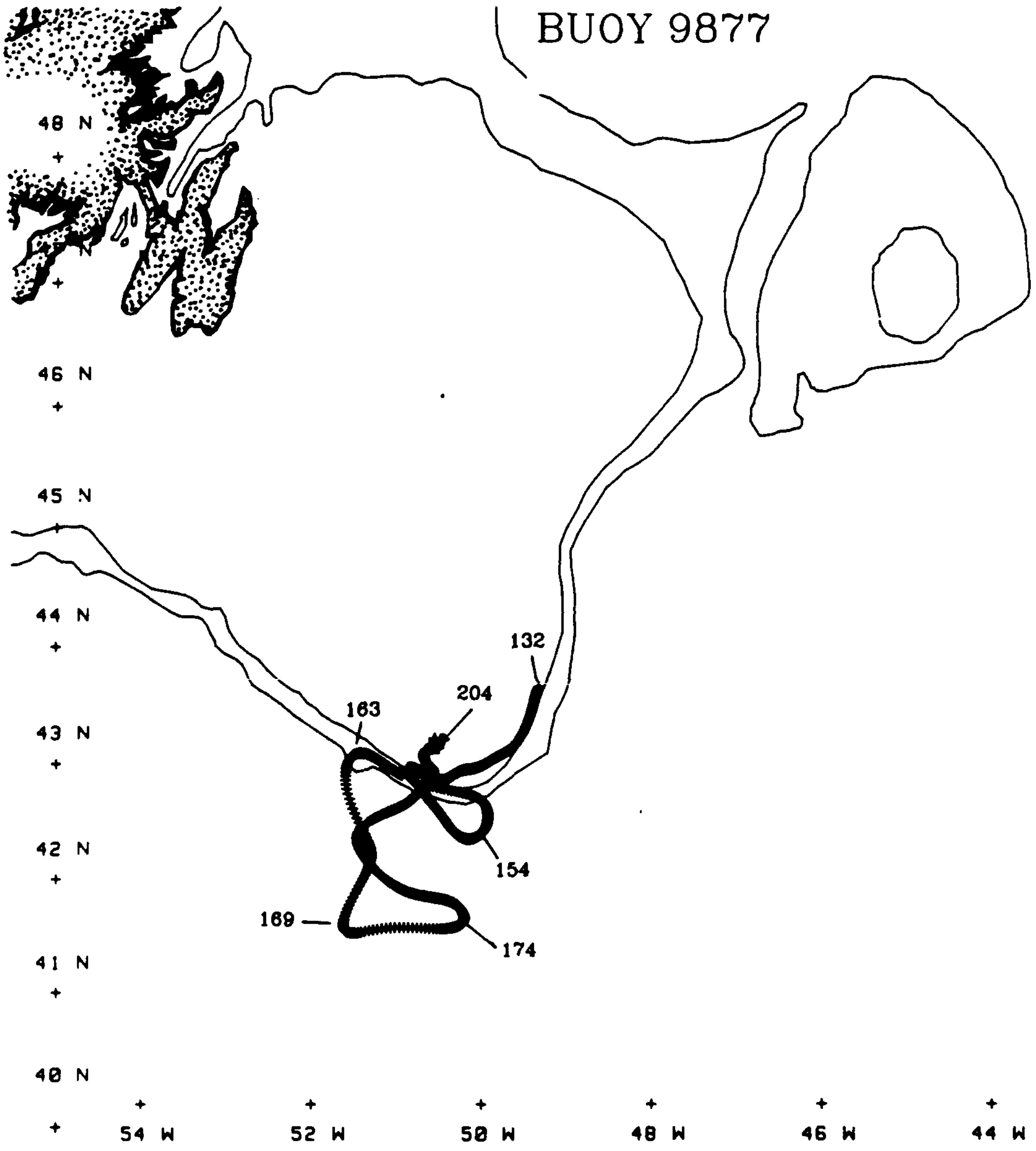

Figure B-2a. Trajectory for 9877

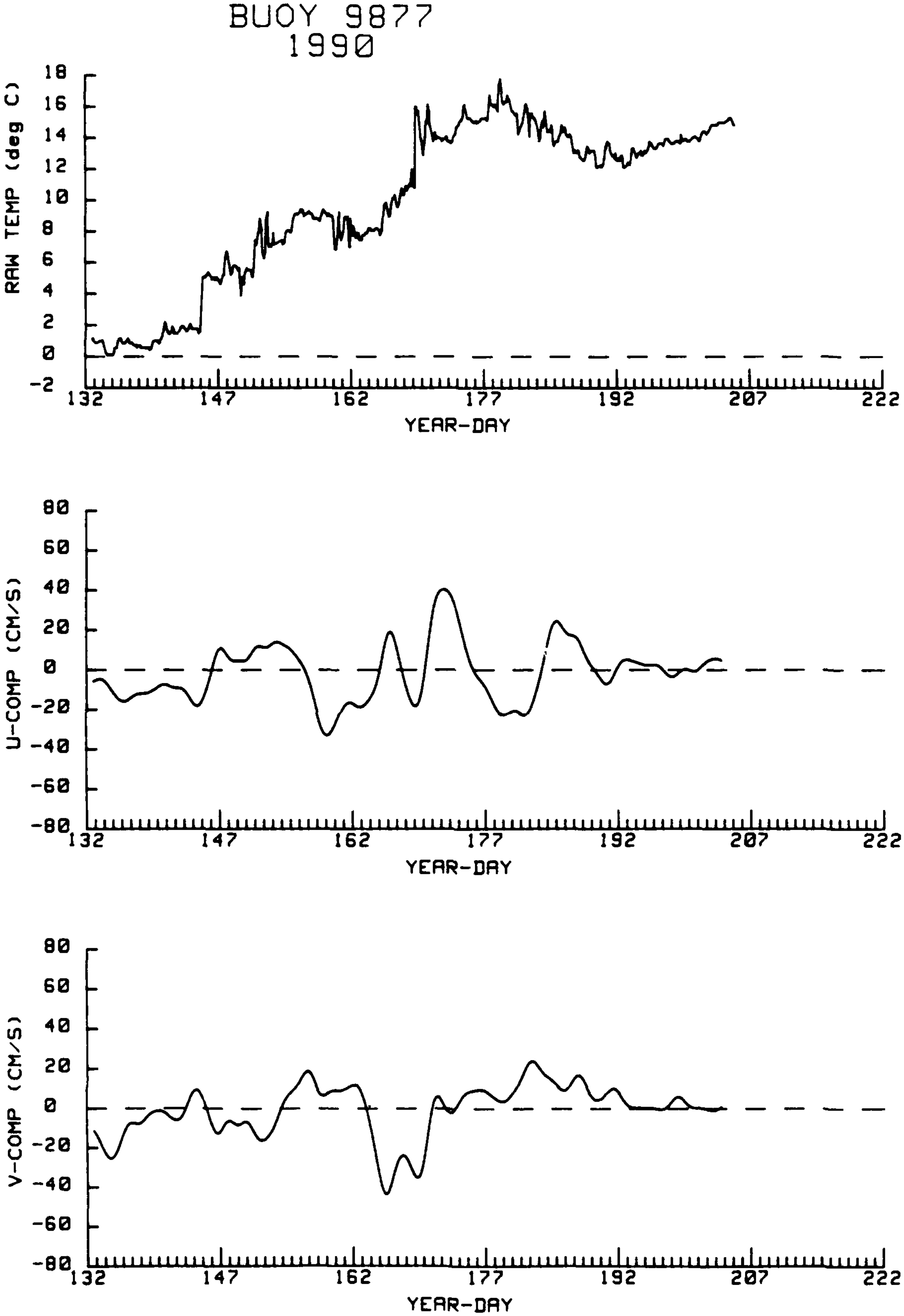

Figure B-2b. Time history of sea surface temperature, U, and V velocity components (filtered) for 9877.

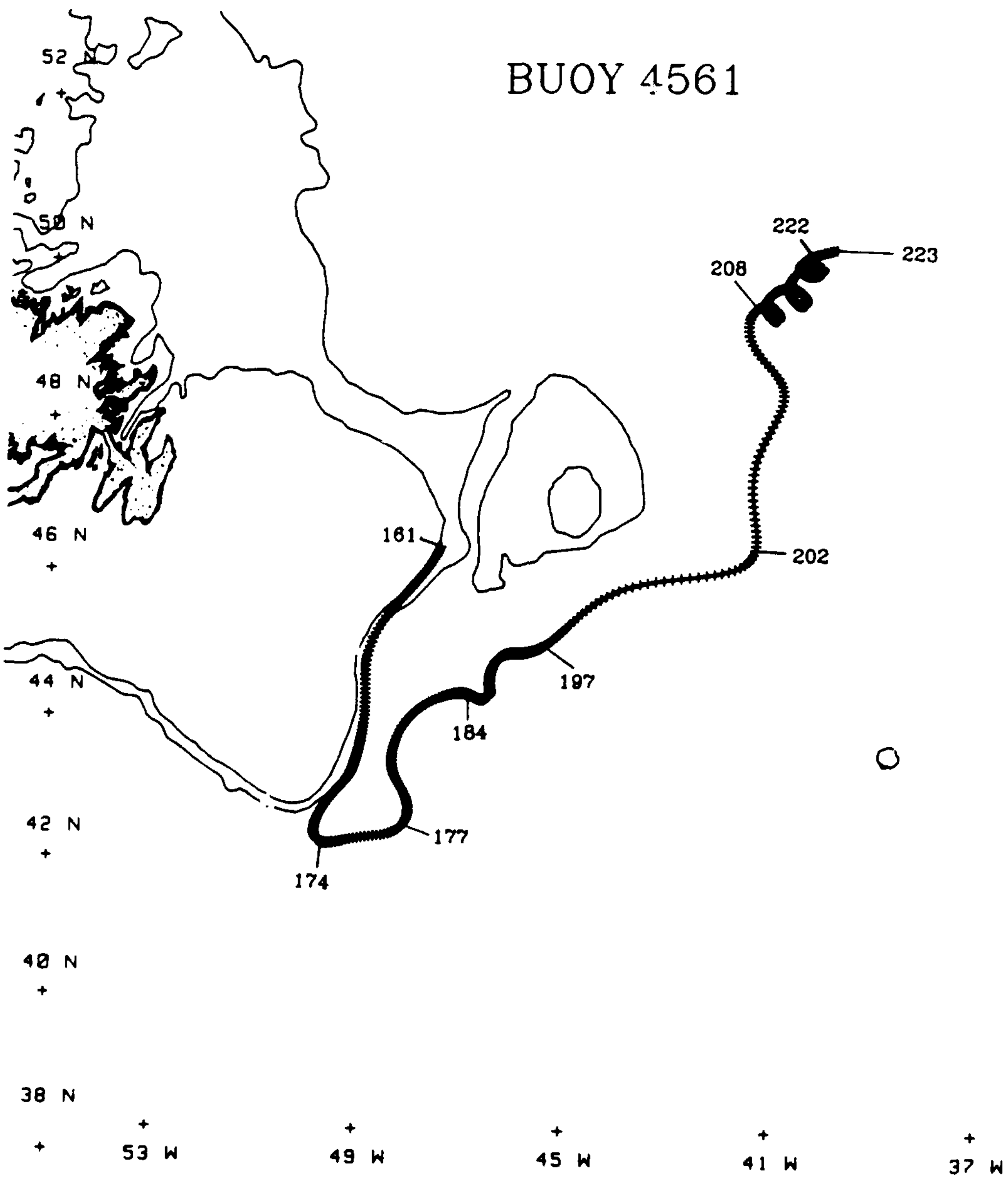

Figure B-3a. Trajectory for 4561

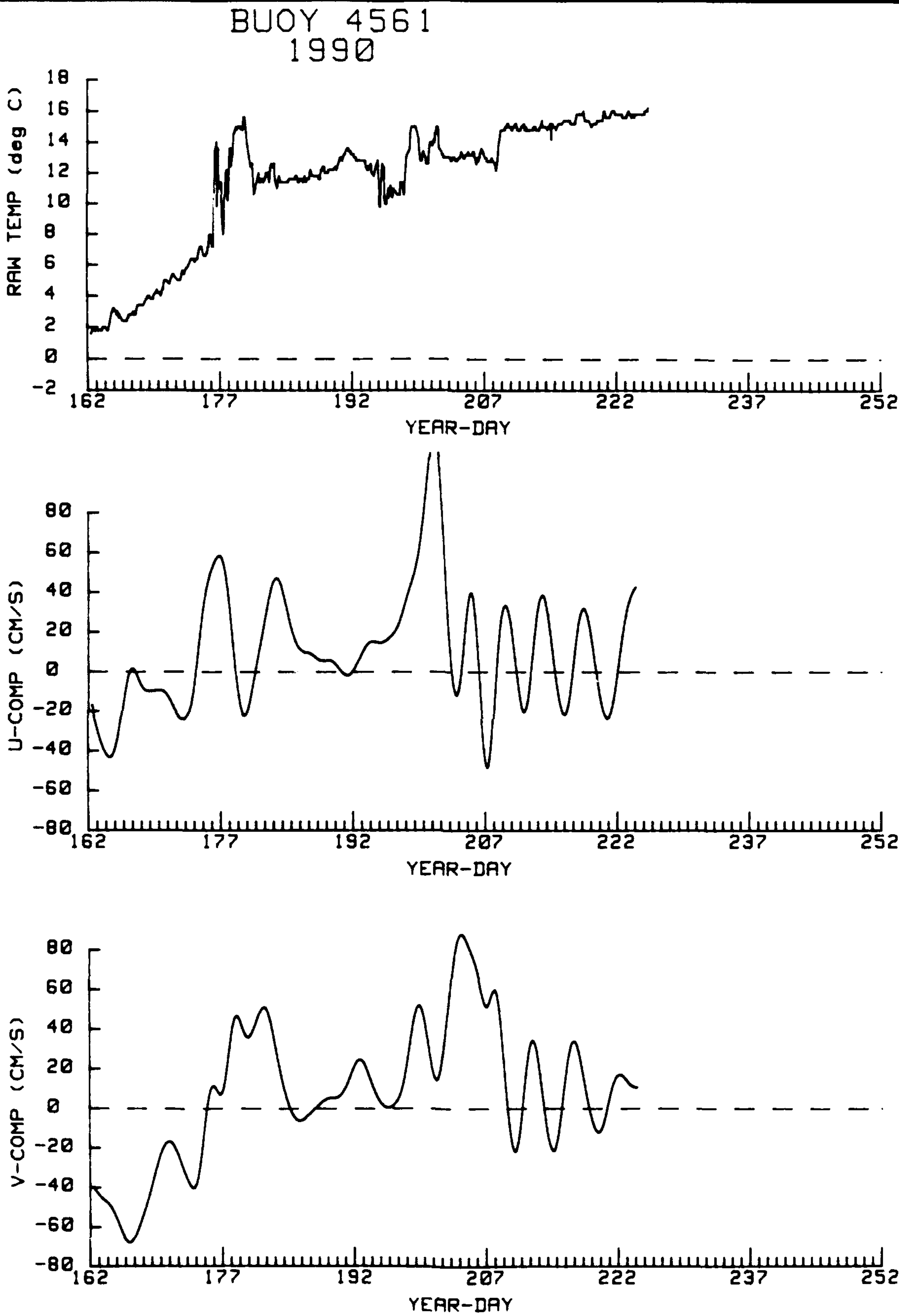

Figure B-3b. Time history of sea surface temperature, U, and V velocity components (filtered) for 4561.

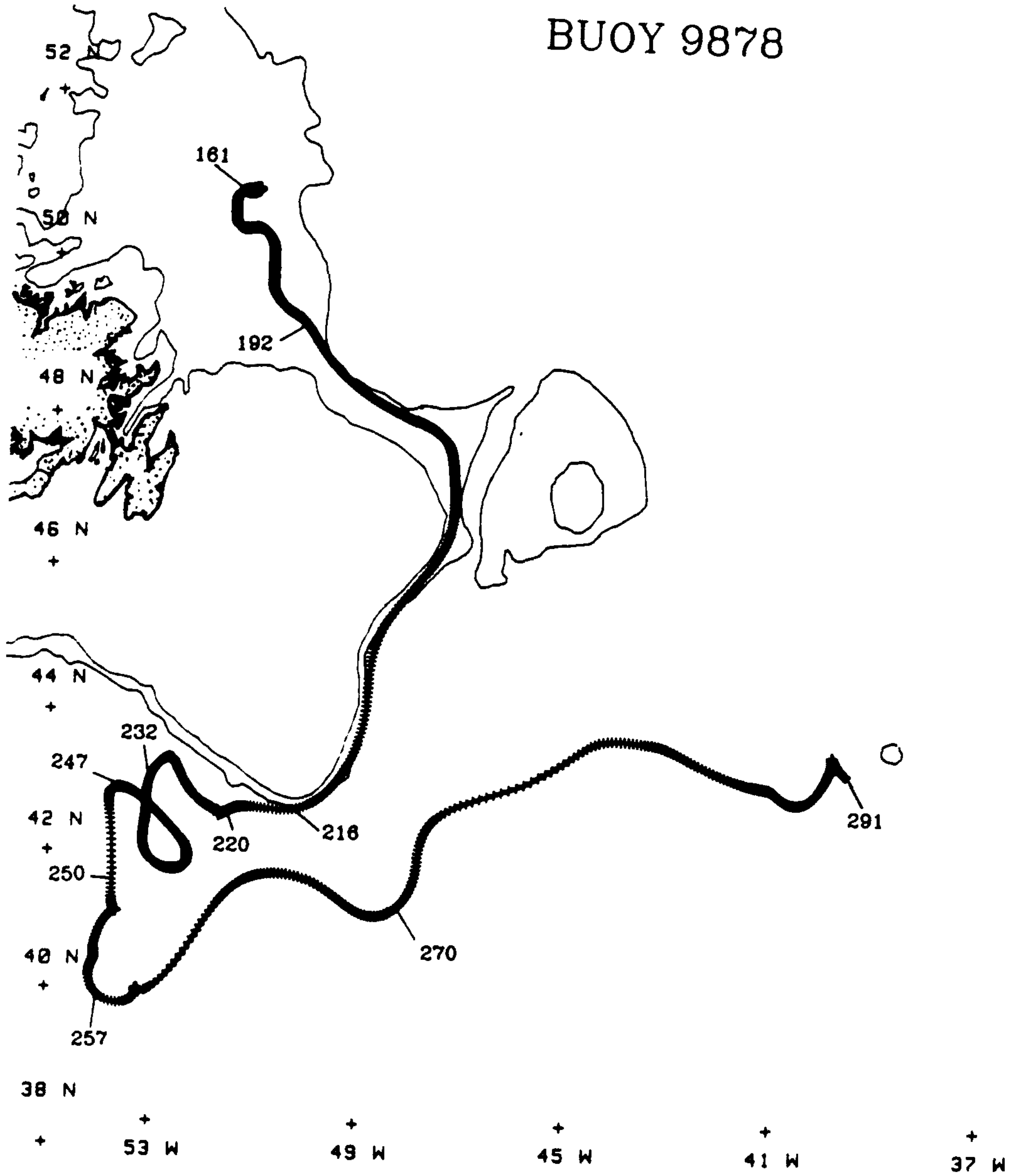

Figure B-4a. Trajectory for 9878

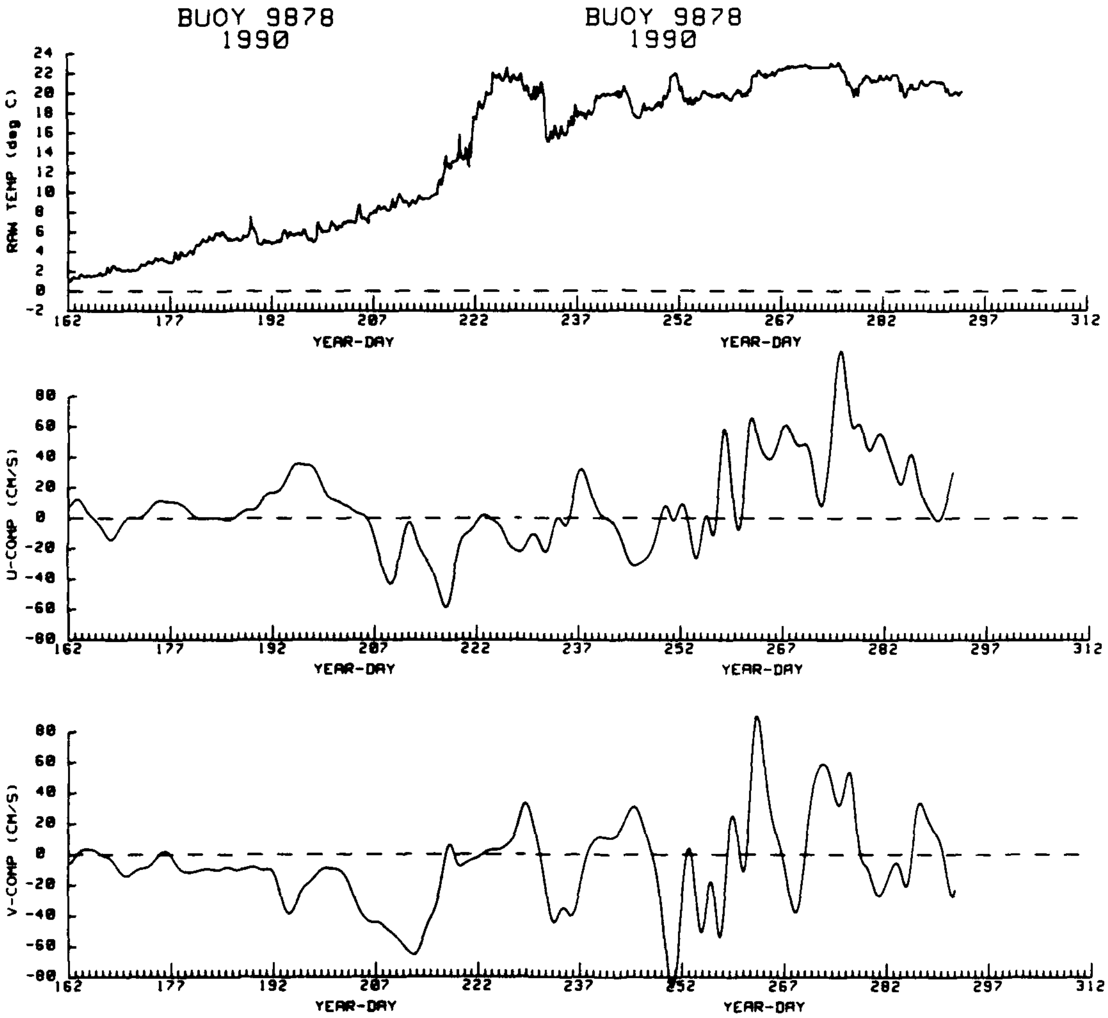

Figure B-4b. Time history of sea surface temperature, U, and V velocity components (flitered) for 9878.

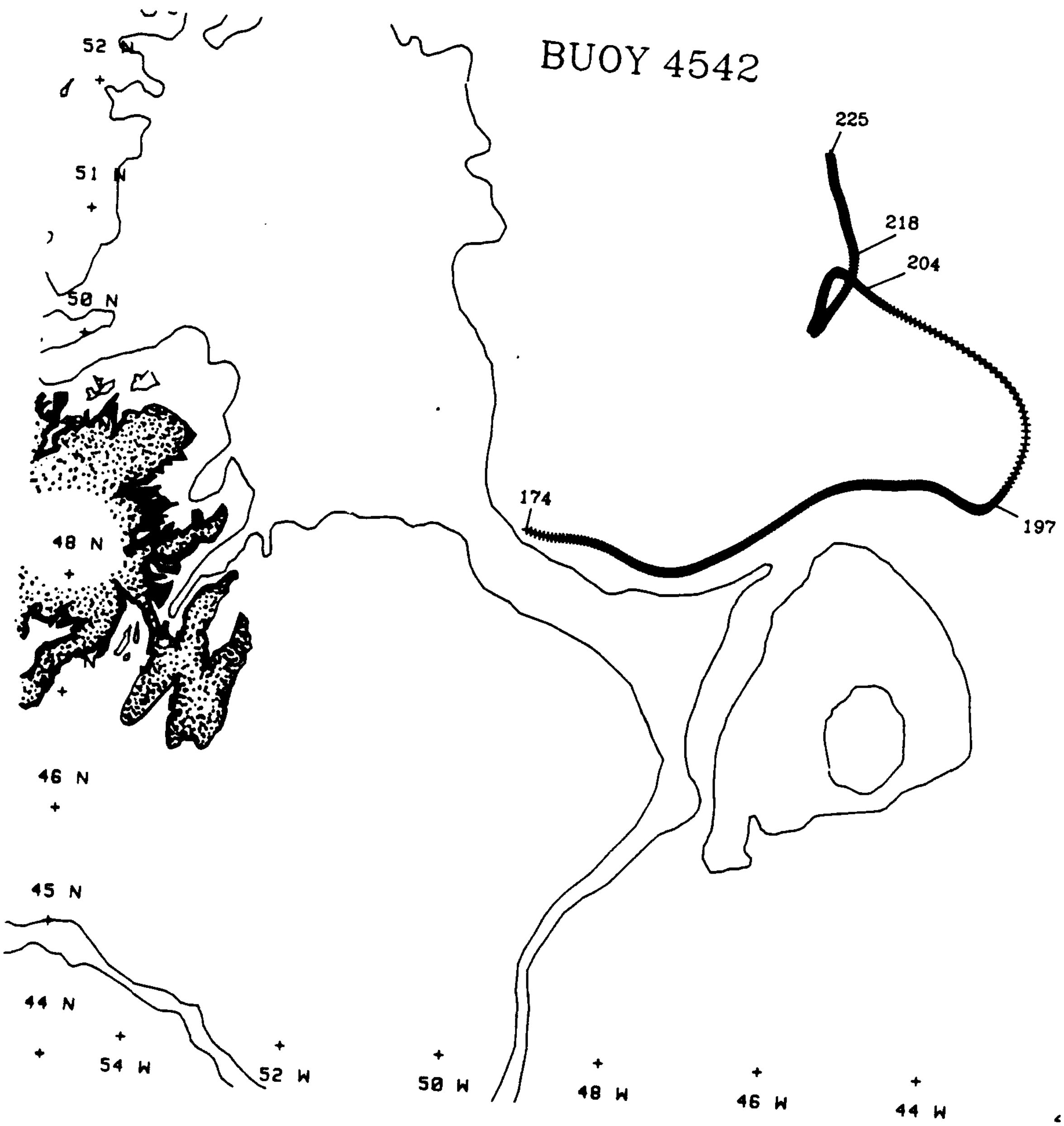

Figure B-5a. Trajectory for 4542.

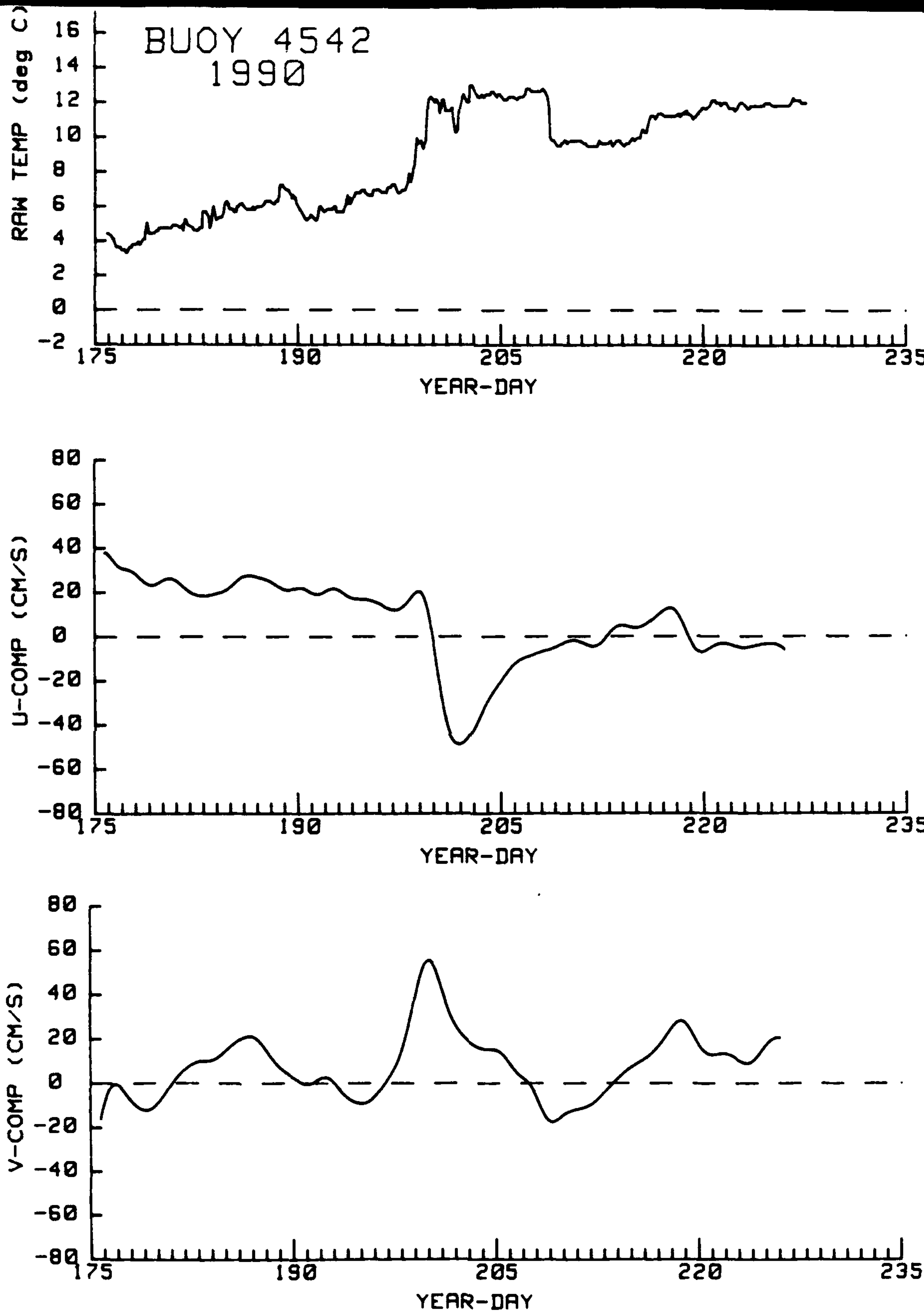

Figure B-5b. Time history of sea surface temperature, U, and V velocity components (filtered) for 4542.

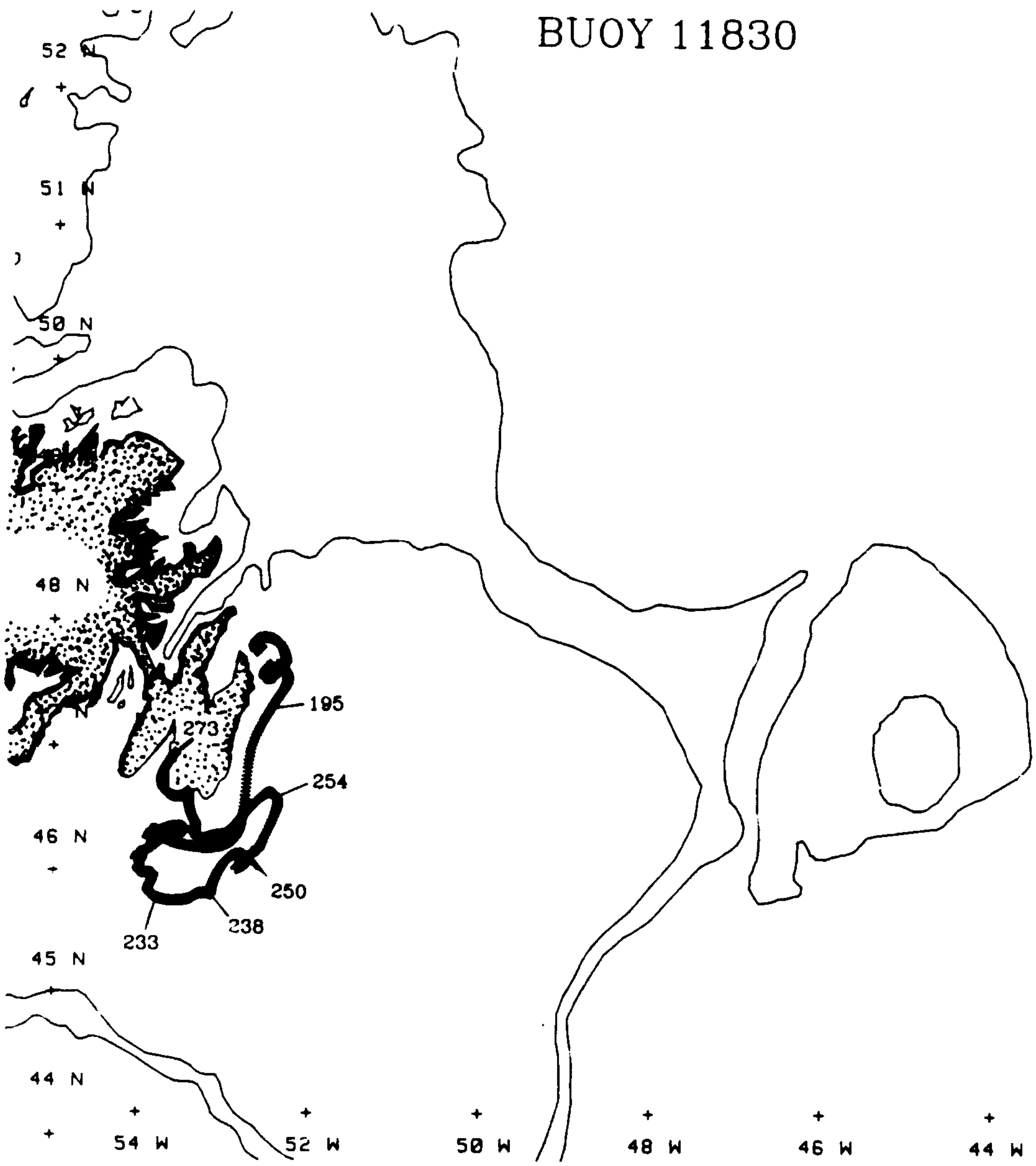

Figure B-6a. Trajectory for 11830.

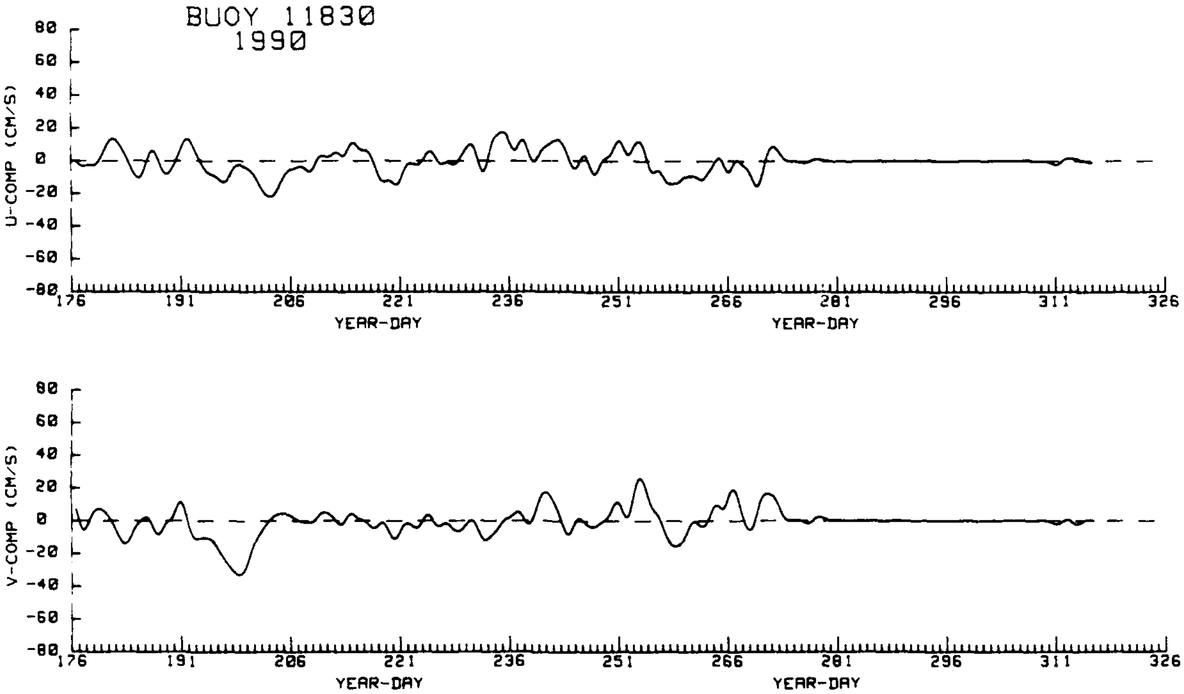

Figure B-6b. Time history of U and V velocity components (filtered) for 11830.

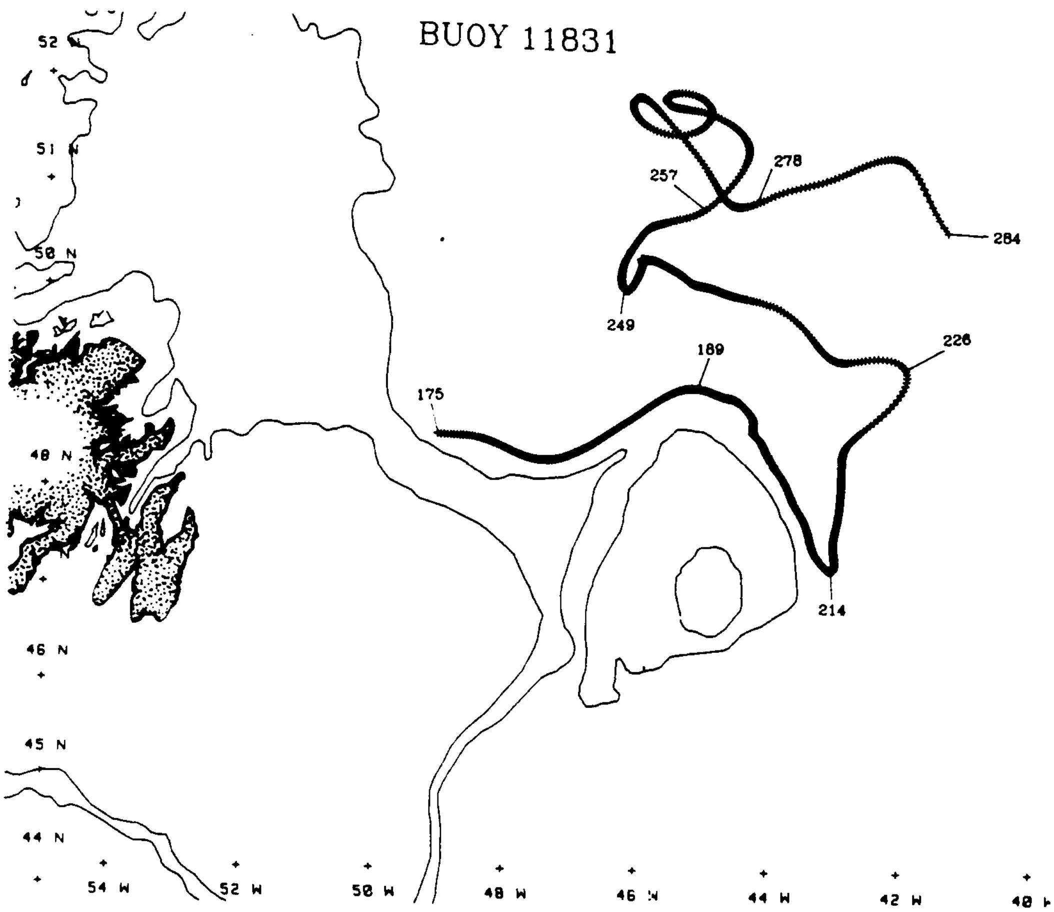

Figure B-7a. Trajectory for 11831

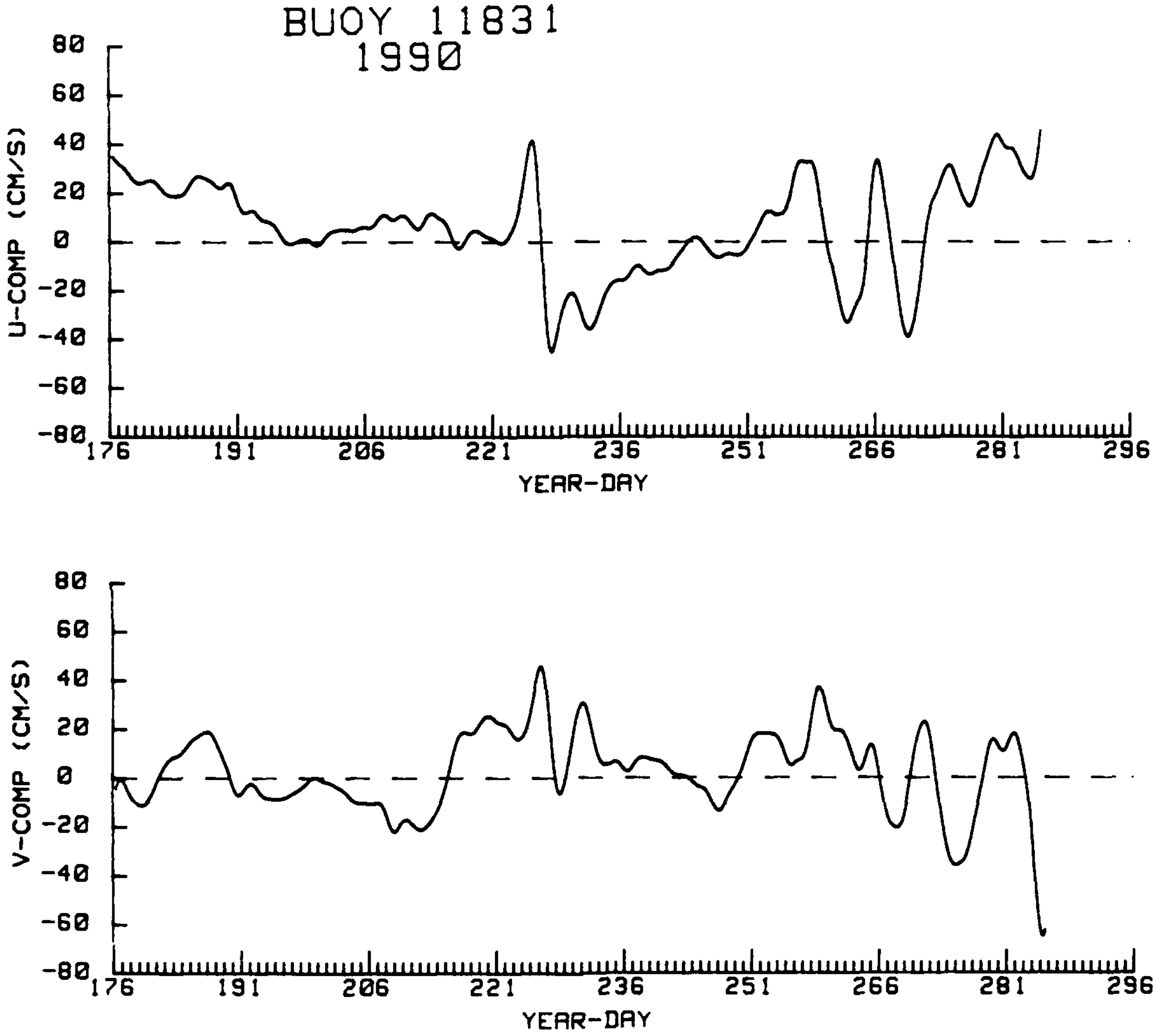

Figure B-7b. Time history of U and V velocity components (filtered) for 11831.

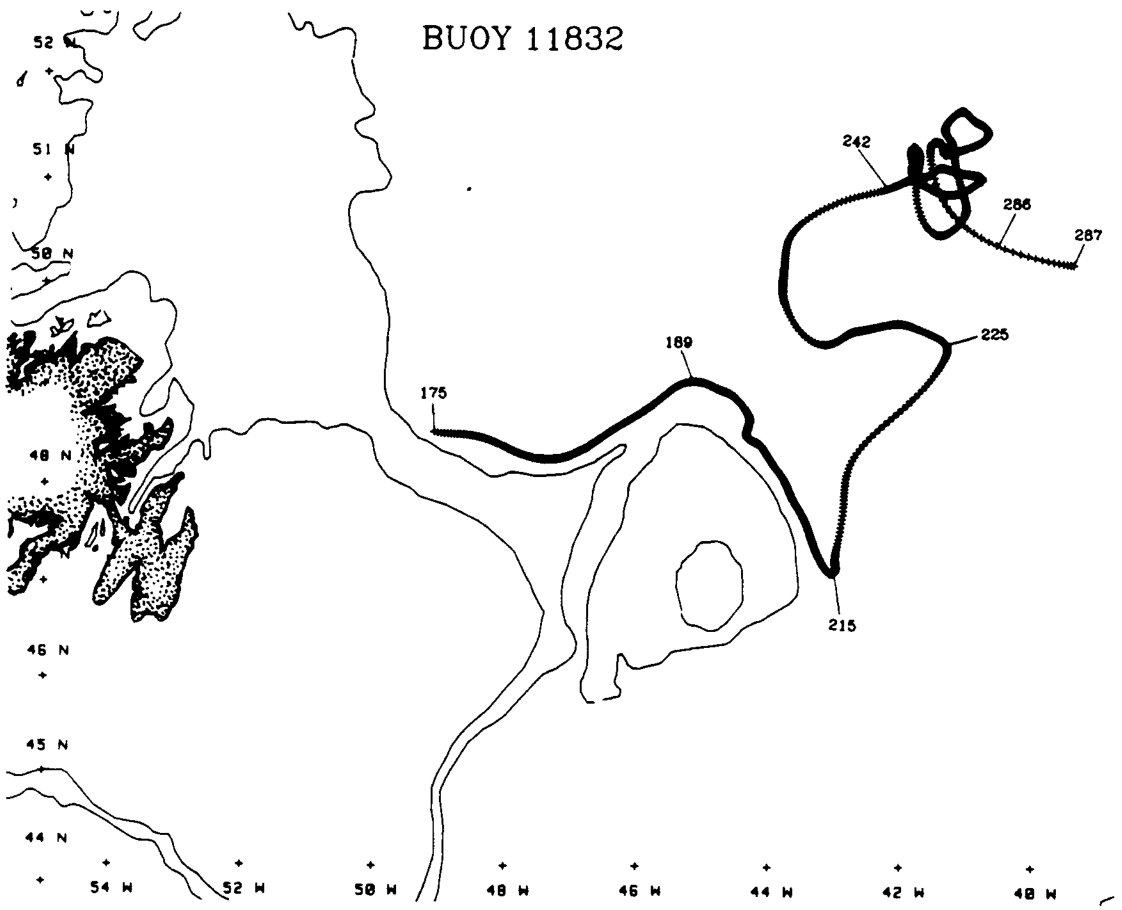

Figure B-8a. Trajectory for 11832.

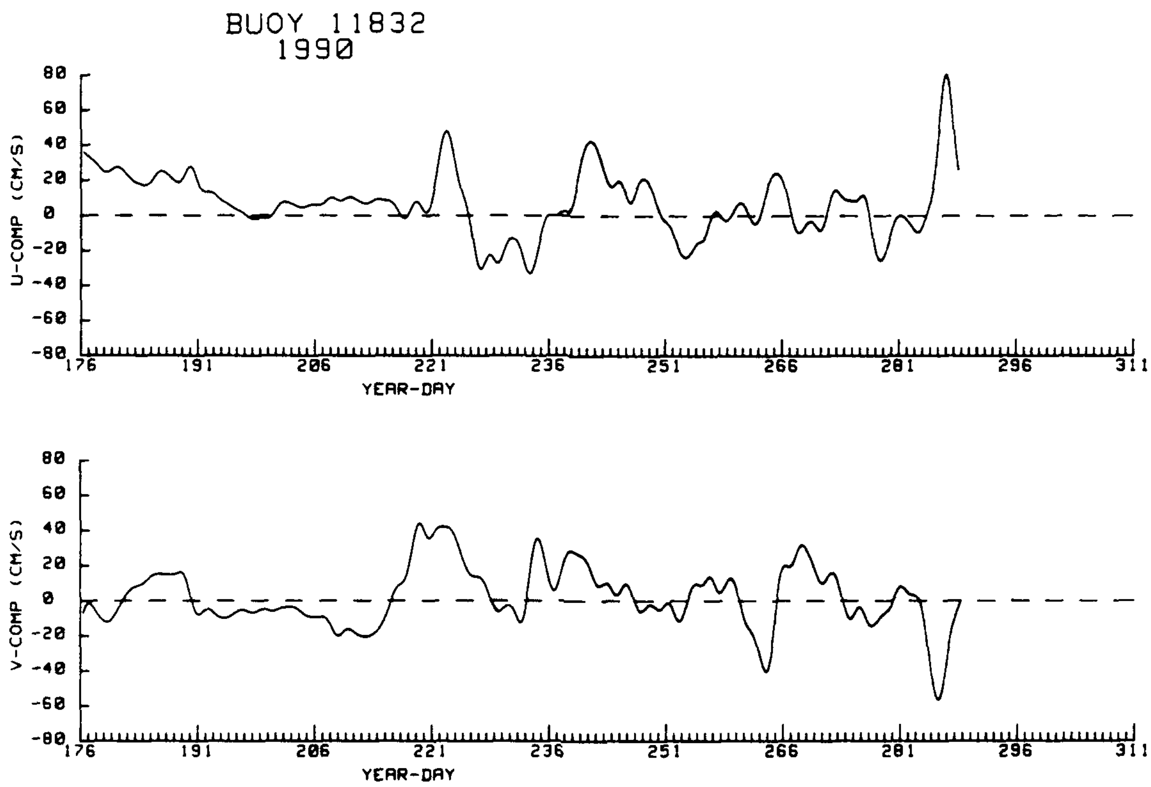

Figure B-8b. Time history of U and V velocity components (filtered) for 11832.

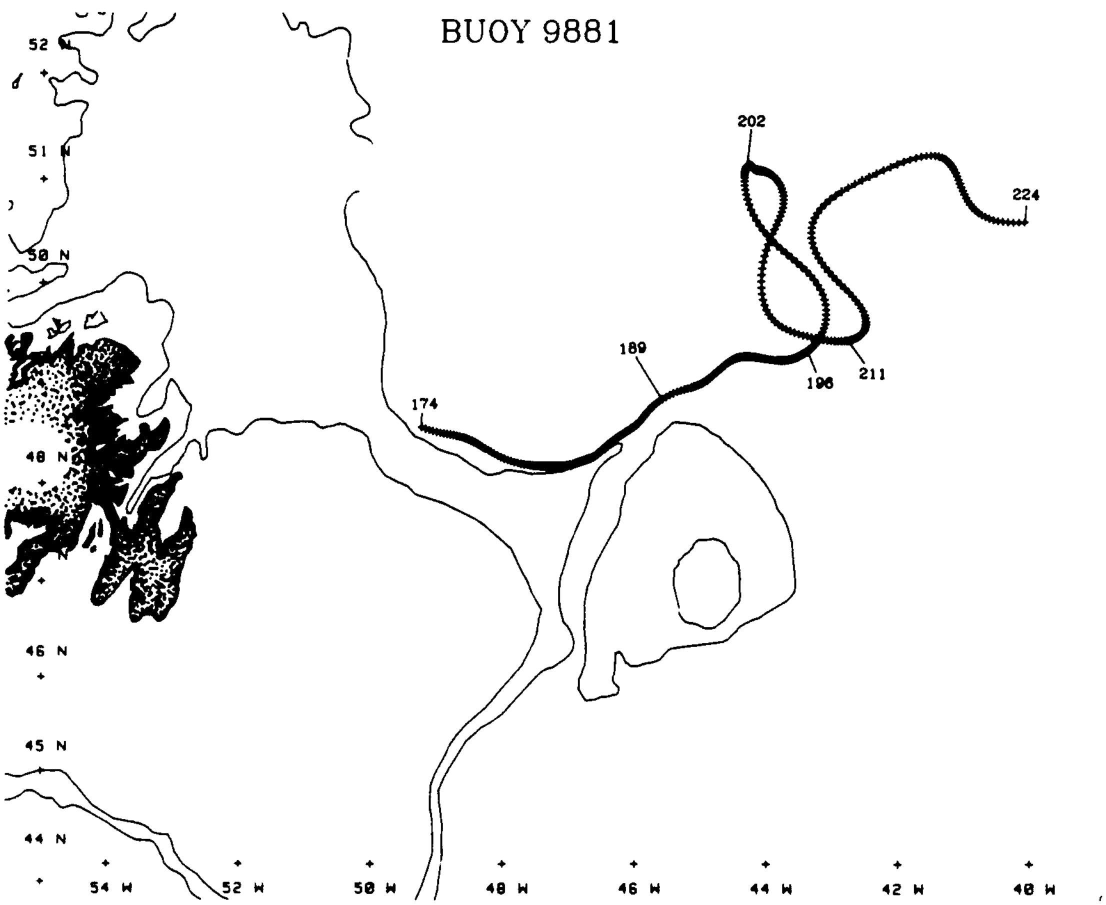

Figure B-9a. Trajectory for 9881.

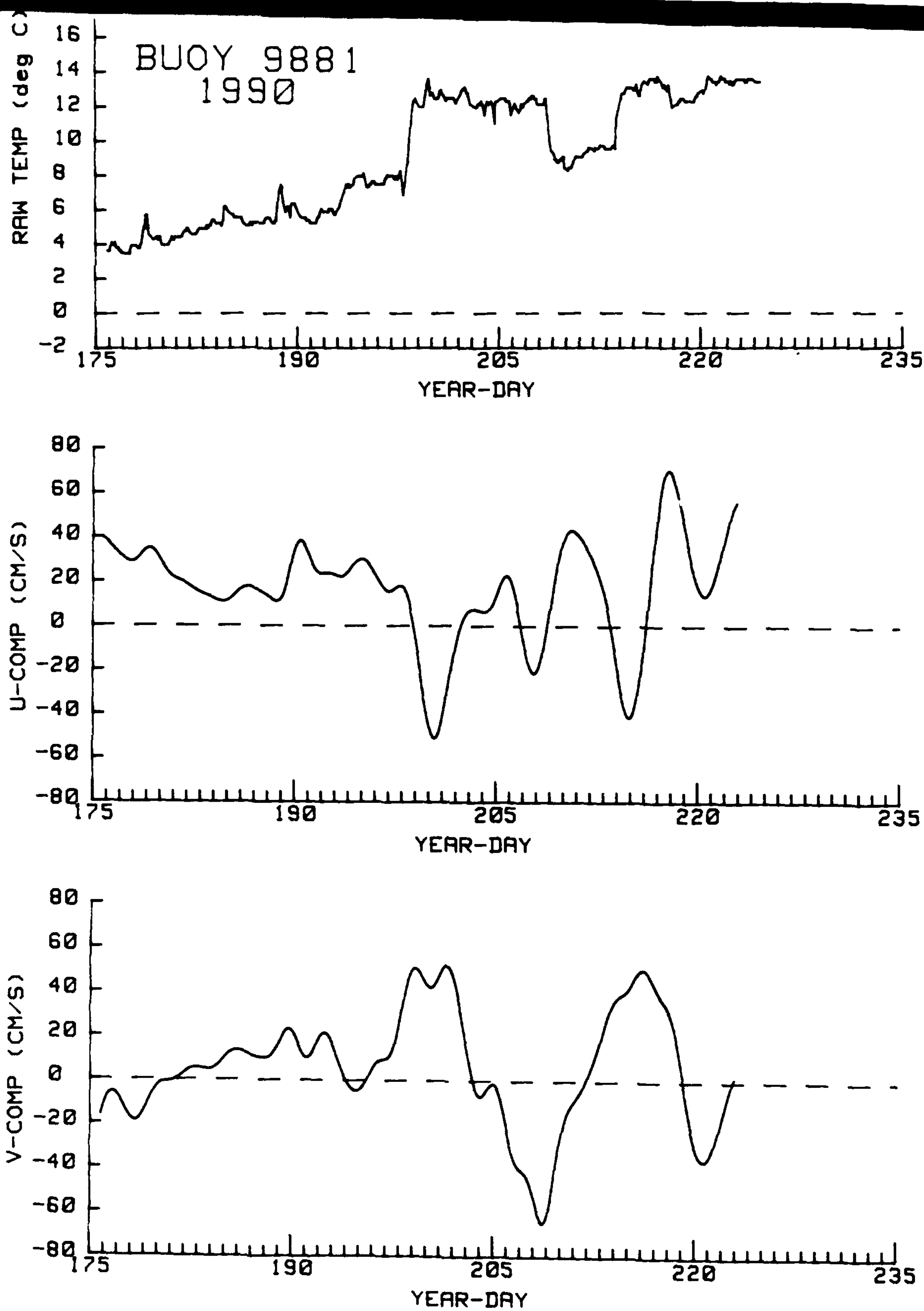

Figure B-9b. Time history of sea surface temperature, U, and V velocity components (filtered) for 9881.

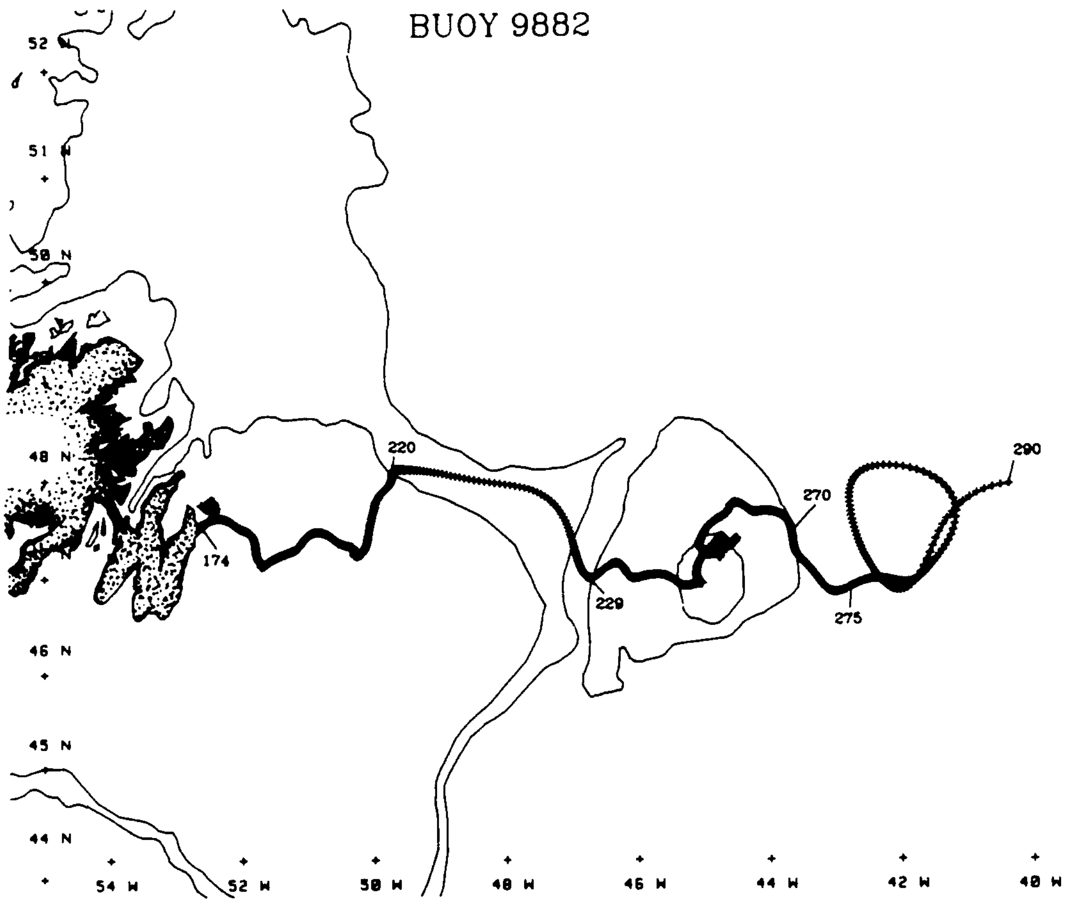

Figure B-10a. Trajectory for 9882.

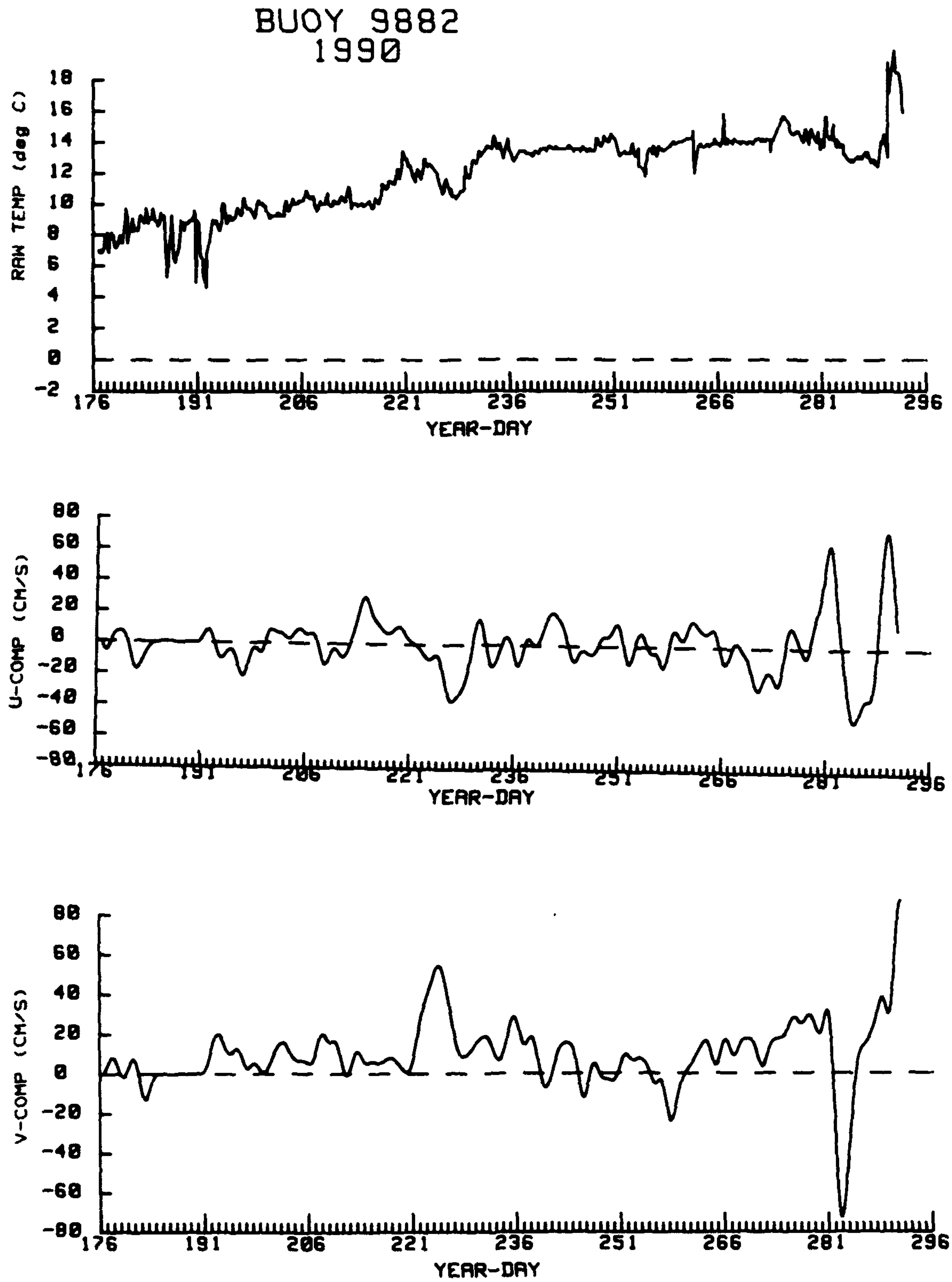

Figure B-10b. Time history of sea surface temperature, U, and V velocity components (filtered) for 9882.

Appendix C

MODIFICATIONS TO ICE PATROL'S MEAN CURRENT DATA BASE

by

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INTRODUCTION

In 1989, the International Ice Patrol (IIP) began an extensive program to review and modify the mean current data base that it uses to predict iceberg drift. This review was made in response to problems identified by IIP watch-standers and the results of research sponsored by the Atmospheric Environment Service (AES) of Canada.

In recent years, Ice Patrol watch-standers have encountered problems in two regions of the IIP operations area: the offshore branch of the Labrador Current and the coastal waters near the island of Newfoundland (Figure C-1). Repeated sightings of icebergs moving southward in the offshore branch south of Flemish Pass showed that the IIP drift model was predicting a southward movement far in excess of the observed iceberg movement. Frequently, iceberg resightings required the watch-standers to intervene and move the icebergs back to the north, in effect slowing the southward progress of these icebergs. In a study sponsored by AES (FENCO, 1987) current meter and drifting buoy data were compared to the mean values in this region. They found that the magnitudes of mean values in IIP data base were 2.5 times greater than the observations.

Along the Newfoundland coast, the IIP current data base had some areas where no mean currents were specified, particularly Notre Dame Bay, which is off the northeastern coast, and the coastal waters off southern Newfoundland. When icebergs entered these regions, IIP's iceberg drift model calculated only wind-related effects, i.e., the mean current terms became zero. As a result, the model calculations showed that icebergs drifting into these regions tended to accumulate there. Reconnaissance showed no such accumulations of icebergs.

The primary goal of this report is to document the changes that were made to the IIP current data base during 1989-1990. In addition, this report summarizes the history of IIP's mean current field and documents the changes that have occurred since it was established.

HOW THE IIP CURRENT DATA BASE IS USED

Ice Patrol's iceberg tracking operation relies heavily on the use of its iceberg drift model (Mountain, 1980). Although aerial ice reconnaissance is the most effective means to survey the operations area to locate icebergs, continuously monitoring the iceberg threat from the air is not practical. For example, Hanson (1989) reported that during a 30-day test period in June 1988, nearly 50% of the icebergs in the IIP operations area were seen only once. This occurred despite an unusually large number of air patrols flown during the period. There were 30 patrols, 17 by the Canadian Ice Patrol and 13 by IIP. However, during the period the iceberg limits encompassed over 1×10^6 km^2 of the ocean's surface and the coverage of each flight was less than 10% of this area.

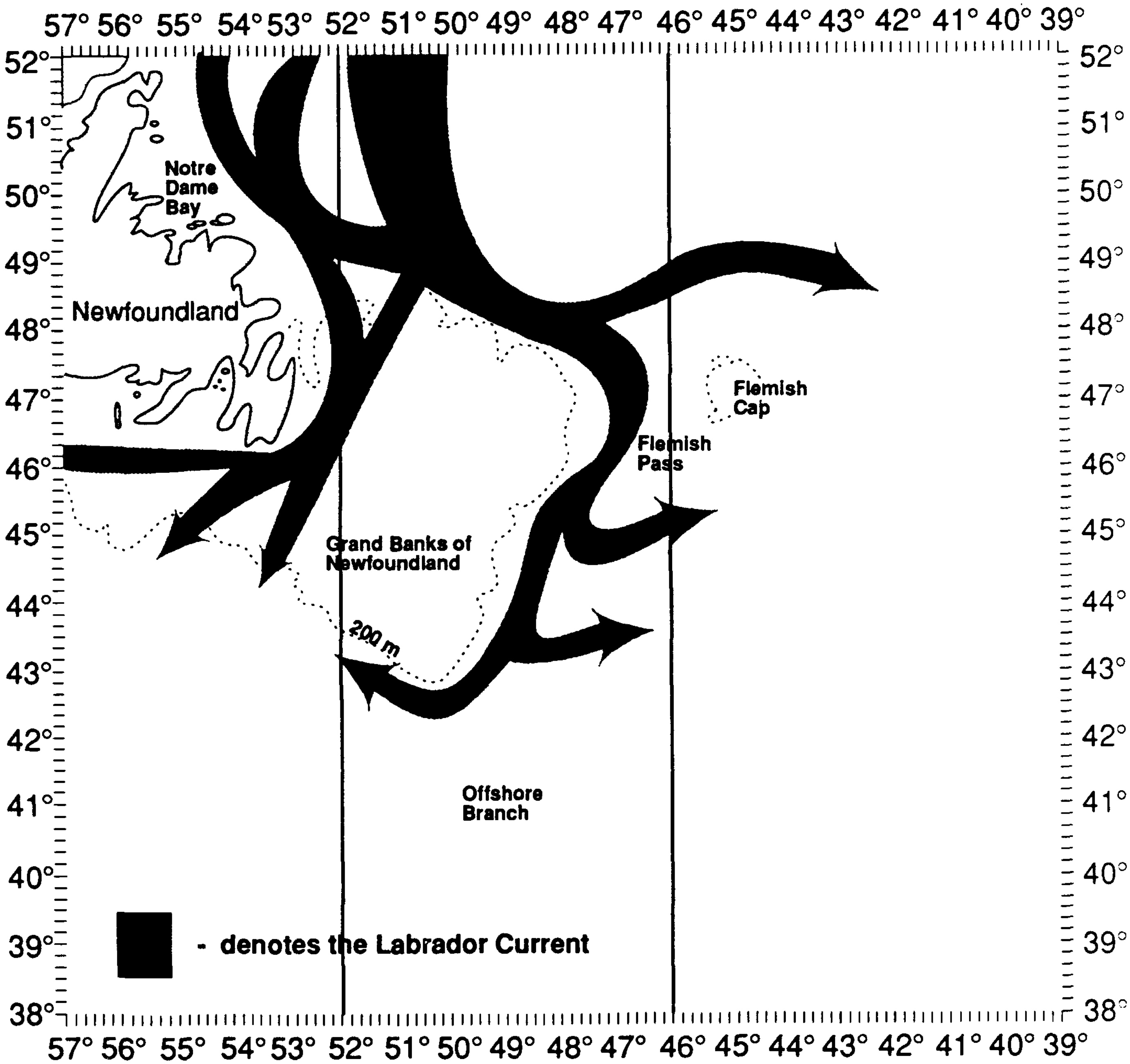

Figure C-1: This figure depicts the Labrador Current, the main mechanism for transporting icebergs South to the Grand Banks.

The iceberg drift model affects all aspects of IIP's operations. It is used to set the limits when no reconnaissance is being conducted. The model predictions are also used to help identify resightings of previously detected icebergs. Without this technique, every iceberg sighting would be viewed as an initial detection, thus greatly inflating the iceberg census numbers.

The accuracy of the iceberg drift model predictions is strongly influenced by the mean currents in the IIP data base. Every week during the iceberg season IIP uses the drift of several satellite-tracked buoys to make temporary modifications to the current data base in the immediate vicinity of the buoys (Summy and Anderson, 1983). When the buoy leaves an area, the currents revert to their mean values over a period of two weeks. Despite this effort to use near real time current data from drifting buoys, the size of the IIP operations area (40-52 N, 39-57 W) and the length of the iceberg season (5-6 months) make it impossible to use only observed data to run the model. Hence, the mean currents of the IIP data base have a strong impact on IIP's iceberg predictions. Ice Patrol uses approximately 12 buoys per year.

HISTORY OF THE IIP CURRENT DATA BASE

The mean current field forms the basis of Ice Patrol's efforts at predicting iceberg movement. The grid spacing varies according to location, with most of the area divided into segments of 20 minutes of latitude by 20 minutes of longitude. The area of the offshore branch of the Labrador Current has a finer longitudinal grid spacing (20' by 10') in an attempt to resolve this narrow, southward-flowing current. This is also the region of the densest (in space and time) hydrographic sampling.

The foundation of the mean current field is hydrographic data collected during over 100 surveys from 1934 to 1978. At least one survey was conducted annually during the period, with the exception of the years of World War II. From these surveys the distribution of mean dynamic typography was computed for each of four months (April - July) by Soule (1964). These charts were updated by Scobie and Schultz (1976). Figure C-2 presents the mean dynamic typography for the month of April.

Until 1979, Ice Patrol used four separate current files, one for each of the four months. However, the monthly variability in the current files was small and in 1979 they were averaged into a single, time-invariant mean current field (Murray, 1979). This field is based primarily on geostrophic currents calculated from the gradients in the dynamic topography. However, in some cases, notably in the core of the offshore branch of the Labrador current in the region south of Flemish Pass, the magnitude of the current was increased from the values calculated from geostrophy to reflect some limited drifter data. There is no documentation for these changes.

The rationale for increasing the current magnitudes was based on the concern that calculating current speeds from the hydrographic data would lead to serious underestimates of the actual current speeds. For example, Soule (1964) argued that the uniform grid spacing of the normal (mean) charts tended to smooth the gradients in dynamic height, resulting in a low estimate of the current

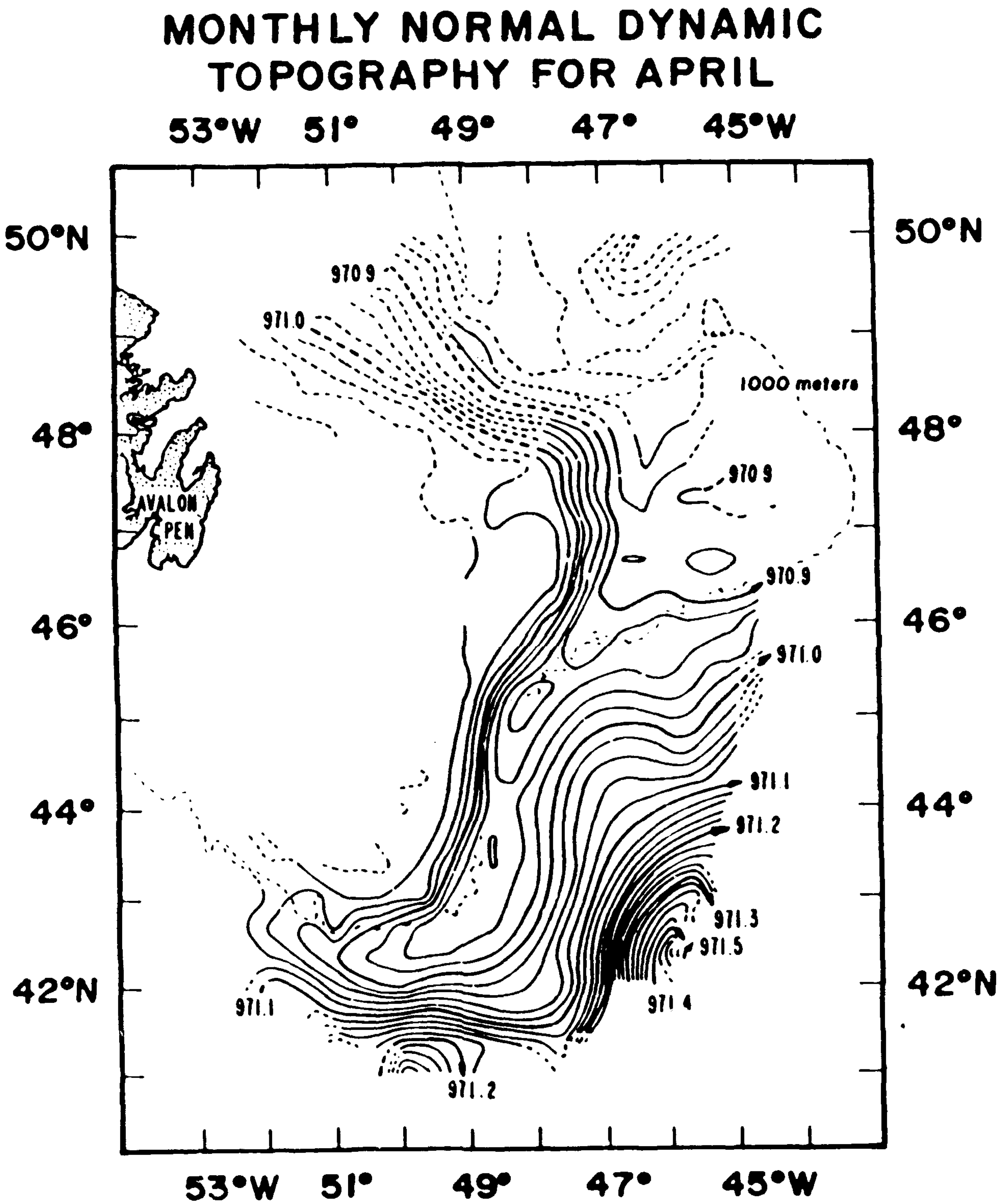

Figure C-2. Mean Dynamic Topography Relative to 1000 db (Scobie and Schultz, 1976).

magnitude. Scobie and Schultz (1976) substantially agreed with this position. They stated that although the current direction can be inferred realistically from isopleths of dynamic height, calculating speeds by taking measurements perpendicular to the isopleths leads to low estimates of the current magnitude. The current magnitudes calculated from the normal charts approach a maximum of 40 cm/s only in a few locations in the core of the offshore branch of the Labrador Current south of Flemish Pass. Other studies, particularly Wolford (1969) suggested that the core speeds were about 50 cm/s to over 100 cm/s. Scobie and Schultz (1976) state that these are more reasonable. Also, using geostrophy to calculate currents has several well known limitations, such as assuming a level of no motion and assuming frictionless, unaccelerated flow. The intent of increasing the Labrador Current core speeds was to be conservative in the operational sense. It was argued that it is better to overestimate the southward movement of icebergs toward the shipping lanes than to underestimate the extent of the iceberg threat to safe navigation.

PREVIOUS CHANGES TO THE 1979 CURRENT FILE

The first documented permanent changes to the data base were recommended by Kassler and Shuhy (1982). They examined the current values in three regions (Figure C-3). In area A, which is bounded by 50 N to 52 N and 51-20 W to 55 W, they based their recommendations on geostrophic current calculations from 393 hydrographic stations and the drift of one satellite-tracked buoy. The hydrographic data included 60 stations taken by a 1981 IIP cruise and the remaining data from the archives of the National Oceanographic Data Center (NODC). Kassler and Shuhy recommended reducing the current speeds in A from 23 to 14 cm/s, which was the maximum average geostophic current calculated in the area. With one exception, the current direction remained unchanged. That exception was in the area of an observed anti-cyclonic loop centered at 51 N, 52 W that was observed in the hydrographic data and the drift of a 1980 satellite-tracked drifter. They stated that the loop was consistent with the bathymetry in the area.

Kassler and Shuhy also compared drifter trajectories from 1979-1981 with the currents in areas B and C. They found good agreement in B and recommended no changes. In area C, the buoy trajectories showed a northward-flowing current in the area from 47 N to 51-30 N and 42 W to 46 W. They calculated the mean buoy drift through the region and recommended that the data base be changed to reflect these values. At a few, isolated locations, marked by X's on Figure C-3, they found some internal consistencies that were corrected. Finally, they recommended the further use of drifting buoy data as a new source for calculating mean currents.

Anderson (1983) used 12 buoy tracks to compute mean currents in three 1° of latitude by 1° of longitude rectangles for the region north of Flemish Pass (48-49 N, 46-49 W). He made permanent modifications to all of the mean current values in the Ice Patrol data base for that region by setting all the values within each 1° by 1° rectangle to the mean value calculated for the 1° by 1° grid.

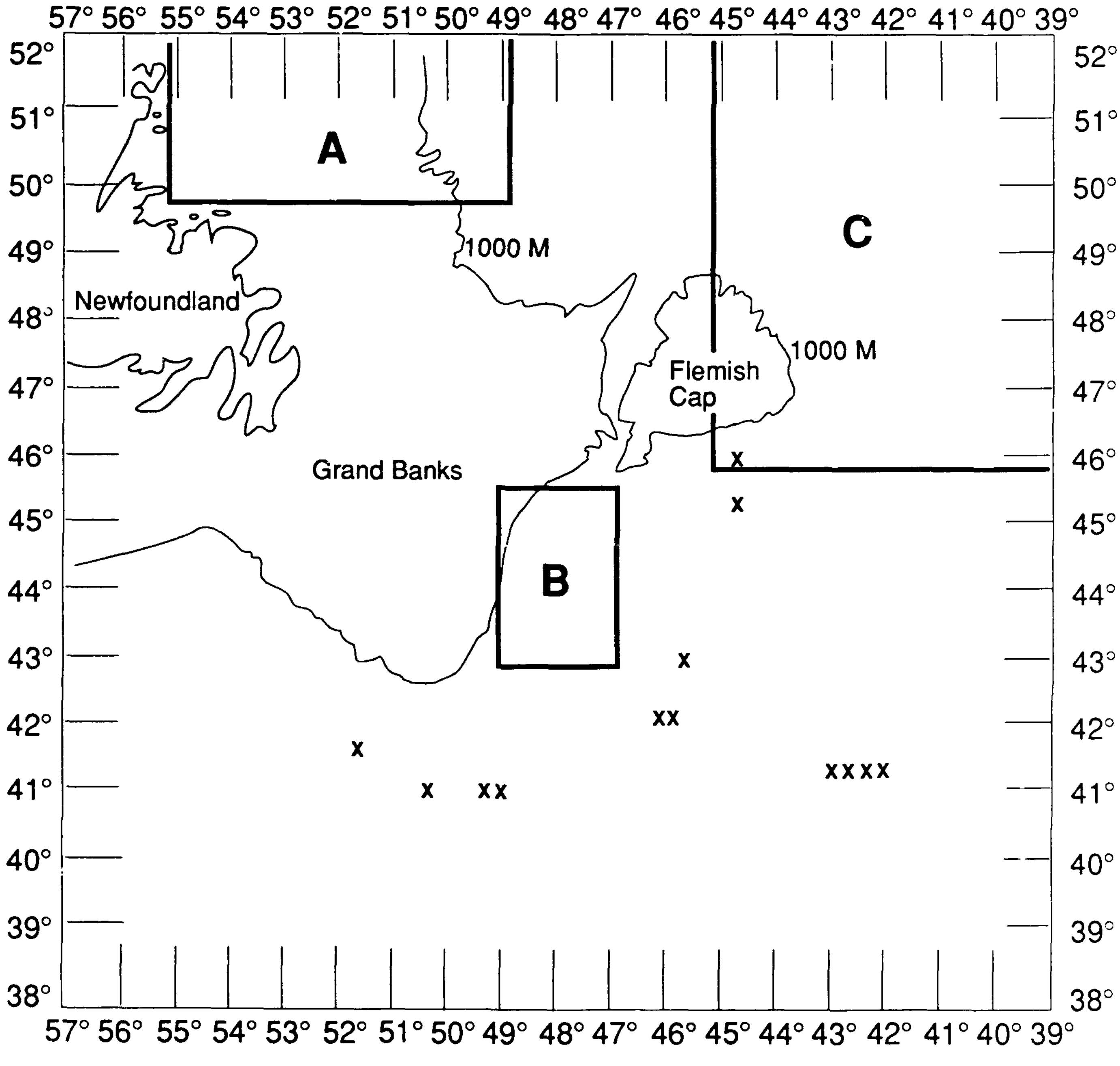

Figure C-3. International Ice Patrol Operations Area showing the areas A, B, and C (Kassler and Shuhy, 1982).

1989-1990 CHANGES

The permanent changes made in 1989-1990 were based on a combination of the drift of the satellite-tracked buoys that Ice Patrol uses in its operations and information gathered from the scientific literature. This section describes the processing of the archived drifting buoy data and presents a brief chronology of the modifications made in 1989 and 1990.

DATA PROCESSING

The drifting buoy data set, which extends back to 1976, now has 125 buoy trajectories with a total of nearly 5000 buoy-days of drift. The trajectories are described in the yearly Ice Patrol Bulletins. The buoy configuration and the position data quantity and accuracy varied over the collection period.

The standard buoy configuration is a 3-m-long spar hull with a 1-m-diameter flotation collar at the waterline. Most of the buoys were equipped with a 2-m x 10-m window shade drogue (some slightly larger) tethered to the hull. Over the 15-year period, the tether length varied somewhat, starting at 10 m (1979-1982), then to 30 m (1983-1984), and finally to 50 m (1985-present). Only data for the period from March through August, roughly corresponding to the Ice Patrol season, were used in the data set.

The number of buoy positions received each day and the accuracy of these fixes varied over the years. During the first few years (1976-1979) the buoys were tracked by the Random Access Measurement System (RAMS) on the NIMBUS-6 satellite. The accuracy of this system was about +/- 5 km and typically, 1-2 fixes were received each day. In 1979 Ice Patrol began tracking buoys with the TIROS satellites, first using a local user terminal at the U. S. Coast Guard Oceanographic Unit (1979-1981), and finally through Service ARGOS (1982-present). This most recent period has the highest quality and most densely-sampled data in time, with position accuracy of about 350 m and 6-10 fixes per day for each buoy. About 70 percent of the data used in the modification are from this period. The trajectories were treated as a homogeneous data set.

All records were scanned and obviously bad positions were removed. The quality controlled position data were then fitted to a cubic spline curve to arrive at an evenly-spaced record with an interval of 3 hours. For most of the tracks, this resulted in no net increase in the number of fixes per day. For the NIMBUS data and the early TIROS data, this process resulted in an increase of data points in the interpolated records. The interpolated position records were then filtered using a low-pass cosine filter with a cut-off of 1.17 x 10^{-5} Hz (one cycle/day). This filter removes most tidal and inertial effects.

The filtered, interpolated drifter data were averaged in bins bounded by the midpoint between adjacent grid points of the iceberg drift model current field. For most of the IIP operations area, this resulted in the grid point that was centered in the bin. Along the boundaries between the two different longitudinal grid spacings (along 46 W and 50 W), this resulted in grid points that were slightly off center in the east-west direction. First, the average speed and direction of an individual buoy that moved through a bin was calculated. Then, the movement of all the buoys that drifted through the area represented by the bin were averaged to arrive at a single mean vector for the bin. This mean vector was calcu-

lated only for cases when there were three or more buoys passing through the bin. These mean values were then blended into the existing data base using a two dimensional least squares spline fit based on IIP's current update program (Summy and Anderson, 1983).

CHRONOLOGY

The first efforts, undertaken before the start of the 1989 iceberg season, focused on the currents in Notre Dame Bay and the coastal waters near southeast Newfoundland. These are the areas that previously had the mean currents set to zero. Because the available current data are sparse, the mean currents in these areas are not well known. The changes were based on current charts provided in Dinsmore (1972), Petrie and Anderson (1983), and Greenberg and Petrie (1988). The latter is the result of a barotropic numerical model. These changes, which were largely subjective, affected fewer than 100 grid points. Most were changed from 0 to 10 cm/s or less and the direction approximately followed the local bathymetric contours.

Early in the 1989 iceberg season (17 April 1989), a permanent modification to the current data base was implemented that included all the buoy data collected in the offshore branch of the Labrador Current up to that time. The data set is described by Murphy and Hanson (1989). The most important effect of this change was the reduction of the speed of the core of the offshore branch in the region south of Flemish Pass from 80-115 cm/s to 40-50 cm/s. There was very little change in the direction of the current in that region. In this area the largest amount of data were collected, with some bins representing the drift of 10-15 buoys.

Between the 1989 and 1990 seasons, a comprehensive revision of the IIP current data base was undertaken using the entire Ice Patrol drifting buoy archive, including the data collected during the 1989 iceberg season. The entire IIP operations area was included in this review, including the areas affected by the permanent modifications made early in 1989. All the grid points that represented at least three buoy tracks were modified to reflect the calculated mean values. In addition to the changes based on the buoy data, the current speeds in two areas were reduced. The current speeds on the Grand Bank and the northeast Newfoundland Shelf were changed from 23 to 7 cm/s. About 200 grid points were affected by this modification. The rationale for this change was that the character of the mean flow in this area is not well known, and that wind effects were likely to be important in the shelf dynamics. Reducing the mean current speed reduced the effect of the mean current on the modeled iceberg drift and allowed the wind-driven terms of the iceberg drift model to play a greater role in the drift predictions. Finally, the currents speeds were reduced in a small area immediately to the east of the offshore branch of the Labrador Current from between 50-52 N. About 80 grid points were affected by this change. The new speeds were approximately half those previously shown in the area. This reduction was required because the speeds in the offshore branch of the Labrador Current were observed to be half the 1979 values.

DISCUSSION

Figure C-4 presents the modified IIP mean current data base as it now exists. The digital data are available on electronic medium upon request. This data base represents our best knowledge of the mean currents in the IIP operations area during the iceberg season, but suffers from the well known problems of mean representations of oceanic circulation. It does not describe well the circulation in areas with significant temporal variability. The temporal variability of the currents in portions of the Ice Patrol operations area is well known (Petrie and Isenor, 1985), so great caution must be exercised when using this data base for drift prediction. Nonetheless, the mean representation of the offshore branch of the Labrador Current in and south of Flemish Pass is well represented in the data base. This area, known as iceberg alley, is of greatest interest to IIP because it moves icebergs southward into the trans-Atlantic shipping lanes. The drifting buoy data clearly support the existence of core speeds lower than the previously used values of 100 cm/s.

Ice Patrol plans to update the data base periodically. As new drifting buoy data become available, they will be incorporated into the data base, most likely every two years. Working with the drifting buoy archive had the side benefit of identifying areas in the Ice Patrol operations area where additional buoys should be deployed. In particular, the inshore branch of the Labrador Current and the northeast Newfoundland Shelf are poorly represented in the data set. Operations permitting, Ice Patrol plans to deploy additional buoys in these areas.

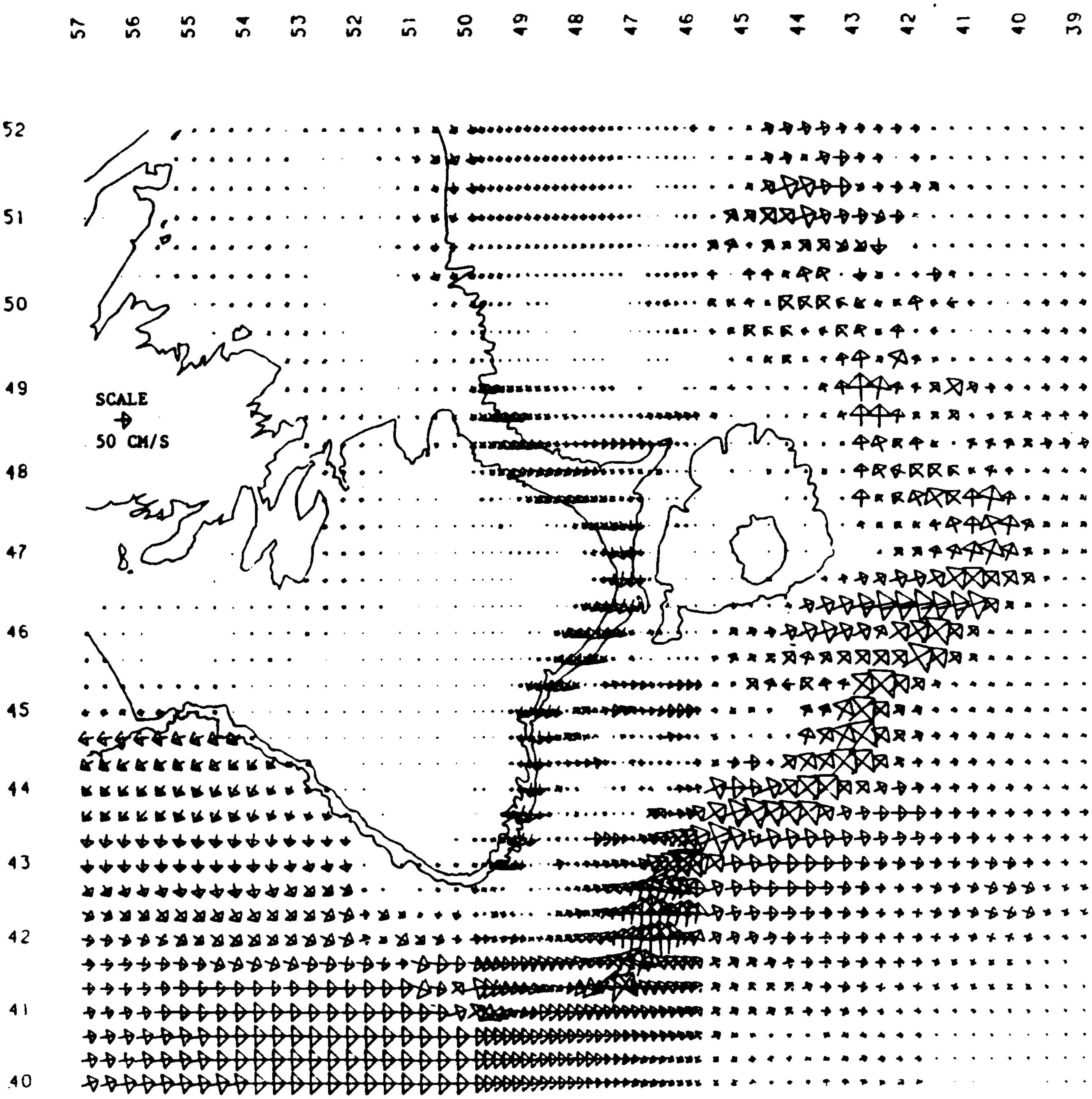

Figure C-4. The Mean Curents in the International Ice Patrol Operations Area after the Permanent Modifications made in 1989 - 1990.

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